# Iron and Steel Engineer

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J. F. KELLY, *Editor*

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Yours very truly,

John F. Kelly

Managing Director
A. I. & S. E. E.

JFK/ak

# EDITORIAL

**The Executive Committee of the Lubrication Engineering Division of the Association of Iron and Steel Electrical Engineers held their first meeting at the Lackawanna, N. Y., plant of Bethlehem Steel Company, October 3, 1930. The following preamble and program was adopted as a start toward the advancement of the application of lubrication in the Iron and Steel Industry. The Executive Committee is as follows:**

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---

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## *Lubrication Engineering Division*

Object—the advancement of the application of lubrication to the Iron and Steel Industry. To promote the study and practice of steel mill lubrication and to accumulate and disseminate data secured in the field of operation.

Among the means to be employed to attain this end shall be the organization of a lubrication engineering division of the Association of Iron and Steel Electrical Engineers to function through specialized committees, periodical meetings for the presentation of papers and the discussion of lubrication subjects pertinent to the industry.

### COMMITTEES AND THEIR FUNCTIONS

**Executive Committee**

The establishment of contacts with the executive personnel of the Iron and Steel Industry together with the mill and machinery builders and also the electrical manufacturers in the United States and Canada to secure information and data in connection with lubrication.

**Engineering Committees**

Design of mills, prime movers, power transmission equipment and machinery, with respect to lubrication.

1. Bearing Design
   a. Bearing pressures
   b. Effect of Velocity
   c. Temperatures
   d. Materials
   e. Grooving

**Records and Accounting**

1. Consumption and cost of lubricants.
2. Maintenance cost through lubrication.
3. Mill delays.
   a. Poor bearing design
   b. Change of bearings
   c. Lubrication devices
   d. Lack of lubrication
4. Power costs and savings.
5. Comparative data and charts for periods lubrication used.
6. Storage and handling of oils and greases.
   a. Methods used for ordering oils and greases
   b. Methods used for storage
   c. Are storage houses centrally located?
   d. Should oils and greases be ordered on basis of tons rolled?

**Proper application of lubrication appliances and devices**

1. Automatic pressure systems
2. Circulating oiling systems.
3. Sight-feed and pressure cups
4. Pressure guns
5. Hand Methods
6. Safey Provisions.
7. Reconditioning of oil

**Specifications of lubricants**

1. Standardization of Practices.
2. Laboratory and mill tests.

**Meetings**

1. Technical sessions under the auspices of the Lubricating Engineering Division of the Association of Iron and Steel Electrical Engineers.
2. National Executive Committee Meetings, (approval, reports, policies, etc.)
3. Sectional Committee Meetings.
   a. Preparation of data, information, reports, papers, etc.

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The IRON AND STEEL ENGINEER, the official periodical of the A. I. & S. E. E. will carry exclusively the transactions of the Lubrication Engineering Division.

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# SYMPOSIUM

# Open Hearth Furnace Control

Presented Before the 26th Annual Convention

*of*

ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINEERS

Buffalo, N. Y., June, 1930

## *OPEN HEARTH CONTROL—*

By H. V. FLAGG, Combustion Engineer, The American Rolling Mill Co., Middletown, Ohio.

## *THE AUTOMATIC REVERSING OF OPEN HEARTH FURNACES BY THE TEMPERATURE DIFFERENCE METHOD—*

By M. J. BRADLEY, Engineer, Leeds & Northup Co., Philadelphia, and J. W. KINNEAR, JR., Assistant Superintendent, Open Hearth No. 3, Carnegie Steel Company, Munhall, Pa.

## *AUTOMATIC COMBUSTION CONTROL FOR OPEN HEARTH FURNACES—*

By R. W. SIMPSON, Assistant Manager, The American Heat Economy Bureau, Inc., Pittsburgh, Pa.

## *DISCUSSION OF OPEN HEARTH FURNACE CONTROL—*

By M. GREENBERG, Pittsburgh District Manager, Bailey Meter Company, Cleveland, Ohio.

## *MACHINE CONTROL OF COMBUSTION IN METALLURGICAL FURNACES OF THE IRON AND STEEL INDUSTRY—*

By J. F. SHADGEN, Combustion Engineer, Smoot Engineering Corp., New York, N. Y.

### *Discussion:*

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# Open Hearth Control

By H. V. FLAGG*

There are four essential factors that influence fuel economy in the open hearth operation.

The first of these is the fuel to be used. The ratio of carbon to hydrogen should be high so that a strong concentration of carbon particles in the flame can be maintained with the resultant high heat transmission. If producer gas is used, the gas house standard of operation must be such as to assure gas of optimum, uniform quality at a steady, non-varying pressure. If liquid fuels are to be used with steam atomization, the mixer must be so designed as to atomize thoroughly with minimum steam consumption and must be free from stoppage trouble. The fuel and steam pressure must be kept regular and constant, and both fuel and steam should be properly pre-heated. If high hydrogen gases, such as coke oven gas or natural gas, are to be used, provision should be made for carburization with other fuels high in carbon such as tar or heavy fuel oil, in amounts sufficient to establish the proper carbon to hydrogen ratio. While the fuel to be chosen is usually directed by local conditions, this principle should nevertheless be kept in mind, since finest open hearth operation requires a high carbon concentration in the flame.

The second factor is that of furnace design. To get the best possible results from the fuel used, the furnace must be properly designed for that fuel. Such factors as the size, shape, and inclination of ports, the distance of the port from the bath line, the establishment of furnace lines that will permit of free passage of the gases, the speed of mixing of gas and air, the size and location of off-take flues, checker design, dampers, both reverse and stack dampers, must all be given proper consideration in view of the characteristics of the fuel which is to be used. It will be necessary to so correlate these various factors that the heat transmission will begin as soon as the flame strikes the bath and will continue clear across the hearth. It will be rarely possible to successfully burn a fuel in a furnace that was designed for another fuel.

The third factor is the training of the open hearth operators. The fuel supply and the furnace design, once worked out, remain more or less fixed, with the exception of improvements that will develop from time to time. However, the training of personnel is a never ending job. Furnace operators must be taught the rudiments of combustion as it pertains to the open hearth furnace so that they can understand the effects of the various factors that enter into heat development in the furnace. They must know the effects of over-ventilation or the use of too much excess air. They must know what the effects will be if the air supply is insufficient; what effect the temperature of the checkers has on their air supply; and what the contribution made by the pre-heat in the air amounts to. They must realize the necessity for balanced checker temperatures. They must realize the effects of uneven reverses on the heat exchange in the checkers, due to unbalanced checker temperatures. They must know the effect of changes in draft, and the things that affect the uniformity of the draft condition. These and many other important factors can only be taught in an organized way to a group of open hearth men through carefully prepared programs, which may include class training, individual training, and continual testing along with the furnace operators so that they may understand the things that will happen in their furnaces. The importance of this sort of training cannot be over emphasized. The best possible fuel obtainable, burned in the last word in furnace design, may secure only mediocre performance if the furnace is in the hands of uninformed or indifferent workmen. Such training is the combustion engineer's responsibility and requires a nice balance between technical training and practical application. Mr. Conway's article in the May "Iron and Steel Engineer" was a very nice example of an outline for open hearth job training.

The fourth factor which we want to discuss is equipment provided to help the furnace operator to get best results out of his furnace, after he has learned the principles involved. This equipment includes all the devices available which we ordinarily include under the term "open hearth control apparatus." No individual is skillful enough to detect the changes in the furnace due to variation in fuel or air supply, draft conditions, or working up his bath, with the naked eye. He must be given some instrument to show him these changes, as they occur, so that he may be able to supply the proper remedy. The idea of driving a modern automobile without a speedometer, fuel gauge, oil pressure gauge, or ammeter, would fill most of us with dismay, yet we ask first helpers to operate a piece of equipment costing some three or four hundred thousand dollars without a single guide to what is happening in the furnace. Hence, the necessity for control apparatus is a very definite one. What form these guides may take is a matter of some question. Given an intelligent first helper with a well designed furnace in good condition, very attractive production and fuel economy may be made with no other instruments beyond a simple indication of air flow such as a differential gauge across an orifice placed in an air duct leading to the air saucer and a simple indication of fuel supply which may be nothing more than a steam pressure gauge on the producer steam supply line. In addition to these, a recording pyrometer showing checker temperatures will be of big value, as well as a draft gauge to show the available stack draft. Any other controls that may be installed can only be refinements of these simple applications.

While the open hearth operation may be placed on a very good basis without any more expenditure than that involved in the guides mentioned, nevertheless there will still be a certain margin of improvement that cannot be obtained without some refinement of control apparatus. This margin must

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stand the cost of whatever control equipment is placed. This should not be construed as meaning that expenditures for control apparatus are not justifiable, for the losses involved in the margin of improvement may be so great as to pay handsome dividends on any investment made in control equipment. There are several different avenues of approach towards working out the control so as to realize the last bit of improvement that is possible. The automatic reversals as governed between balancing of heat in the checkers is a very definite step towards better furnace control. The control of the combustion condition in the furnace through analysis of outgoing flow gases offers some possibility. Automatic draft regulation can be of great assistance.

Equipment designed to so proportion fuel and air supply that the combustion condition remains consistent has its merits. The chief draw back of all these controls is that they are not human and cannot be expected to correct for conditions over which the first helper only can have control. However, the proper correlation of intelligent operation with the sufficient control equipment, as we have mentioned, is bound to result in a standard of furnace operation that will pay handsome returns.

# *The Automatic Reversing of Open Hearth Furnaces by the Temperature Difference Method*

By M. J. BRADLEY† and J. W. KINNEAR, JR.*

The open hearth process is the economical method, at the present time, to make steel in large tonnage volume. In fact, it dominates the steel manufacturing processes. This is due, at least in part, to the close control which is possible over the contributing factors.

Temperature is one of the most important factors. The chemical reactions taking place during the heat are directly influenced by the temperatures prevailing during the time the reactions are taking place. For example, it is desirable to have the scrap melted down as rapidly as possible to prevent excessive oxidation. This shortens the time of the heat and permits the addition of more oxidizing agents, such as ore, to be added during the later stages. The exact time to add the hot metal to the charge is governed by the temperature of the materials on the hearth. This temperature should be above, or at least, as high as that of the melting point for pig iron. This statement does not imply that the scrap which has a much higher melting point than pig iron should be completely melted. Indeed, a delay in the addition of the molten metal until the scrap is all melted may be undesirable. It not only causes excess oxidation of the scrap, but the high temperature combined with the excess oxides present would result in a too violent reaction, and much foaming of the bath and loss of metal, due to the rapid generation and evolution of carbon monoxide, would result. Later on in the purification period, it is desirable to keep the furnace temperature higher than the bath temperature to prevent the latter from chilling during the ore and lime boil. If this happens, a foamy slag may result which acts as an insulating blanket to the bath, and decreases the rate at which heat can enter the bath. At the same time, the temperature of the melting point of the bath raises as purification proceeds. These effects demonstrate the necessity for increasing the furnace temperature as purification proceeds. In the working period, or during the final stages of the heat, after all the impurities except carbon have been eliminated, the operations are confined to regulating the properties of the slag, adjusting the carbon content of the steel, and raising the temperature of the bath to the point where the steel may be tapped from the furnace, and cast into ingots before it begins to solidify. These examples are mentioned to illustrate the dependence of the open hearth process on temperature conditions.

The high temperatures required to make steel by the open hearth process are obtained by using the regenerative method. That is, a part of the sensible heat from the gaseous products of combustion is absorbed and stored up in brick surfaces to be regenerated and carried back into the furnace as preheated air for combustion. Producer gas is generally preheated in a similar manner. In order to maintain the preheat at a sufficiently high temperature the system must be reversed frequently.

The most decided advantage resulting from the use of preheated air is due to the fact that all combustion reactions are greatly speeded up by increasing the temperature and, therefore, with a high preheat it is possible to burn fuel completely with much less excess air than would be required if cold air were used. This permits rather close control over the furnace atmosphere and also prevents excessive heat losses up the stack by not using a large amount of excess air over that required for combustion. Information on the speed or velocity of combustion reactions is not complete. It is stated in the literature that for the combustion reaction $C+O_2=CO_2+174{,}600$ B.T.U. if measured at 662°F, and the relative velocity designated as 1, that if the temperature is increased to 752°F the velocity is increased 10 times. When the temperature is increased to 932°F, the relative velocity is increased 400 times. This illustrates why the preheat cycle should be kept balanced on two ends of an open hearth furnace to insure equal flame temperatures from each end. This can be accomplished by holding the reversing cycle within the proper temperature limits.

It will be evident that on every reversal the temperature of the furnace will be higher, for not only

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will there be a normal increase due to the continued action of the flame which would result in any system, but there is a further action peculiar to regenerative construction because the gases passing through the chambers are hotter on every change in direction and produce a more intense flame temperature during combustion. Thus, the action is accumulative and there is a constant increment of temperature increase throughout the whole furnace system. It must be remembered that the difficulty in an open hearth furnace is not to be able "TO REACH" the necessary high temperature, but it is to be able "TO CONTROL" the high temperature and to prevent the roof, ports, and walls from melting during the heat.

The preheat cycle, or the temperature to which the air is preheated immediately after reversing and the decrease in temperature until the following reversals take place, is partially a function of temperature, heat head or volume, the velocity of the air through the checker chamber and the time-temperature effect between reversals. The degree of the preheat cycle may or may not be equal per unit time on the two regenerative systems.

In the usual open hearth furnace operation, the preheat cycle is controlled by having the reversals made on a time basis. The time interval between reversals varies over wide limits in different plants, and not so long ago averaged over twenty minutes. At the present time, a shorter period is favored and averages approximately fifteen minutes. An exact schedule is never maintained because the first helper is often confronted with urgent duties which have to be taken care of immediately. The following quotation taken from the conclusion of a heat study made on an open hearth furnace by Sidney Cornell, and published in "Chemical and Metallurgical Engineering" Vol. XI, No. 5, Page 266 demonstrates how irregular the reversals may be.

"On one of the furnaces from which this heat balance was figured, there were 509 reversals for the week. The average time between each reversal was 10 minutes, the longest time on one set of regenerators was 70 minutes, and the shortest time was 2 minutes. This practice leads to irregularities in the operation of the regenerators, and soon there is a good and a bad end of the furnace. A long period and then a short period on a regenerator naturally does not give a proper distribution of heat to the regenerators, and one set will be at a lower temperature than the other. At certain periods in an open hearth heat it is necessary to have quick reversals, but there is no reason why these reversals should not and could not be made of equal duration for each set of regenerators, thereby maintaining them at balanced temperatures."

It is very difficult, under operating conditions, to keep the regenerative systems on the two ends of the furnace balanced which is absolutely necessary in order to maintain the same uniform cycle of preheated air for combustion from both ends. Not only do the irregular reversals upset the balanced conditions, but many other irregularities in operation also cause the two systems to be operating at different temperature cycles. For example, air leaks, unequal draft conditions, partially blocked checkers or flues, ports and bridge walls burned away, etc., etc. The difference in the cooling rate in the two systems during hot repairs on end walls, ports, arches, burners, and other repairs when the fuel is off the furnace for a few hours or during the week end shut downs, makes it difficult to keep the systems balanced. In fact, during the tapping and charging periods the two ends often become greatly unbalanced. If the heat is started under these conditions and reversals are made on exact time intervals on each end, the furnace is held unbalanced throughout the heat. In fact, it tends to become gradually more unbalanced, unless the reversals are made at very short periods. approximately 5 to 8 minutes. The first helper's attention is drawn to the unbalanced condition due to the fact that the luminosity and length of the flame is greater from one end of the furnace than from the other. He can check the conditions by looking through the peep holes into the checker chambers.

The present operating method to balance an unbalanced open hearth regenerative system is to hold the furnace much longer on the hot end than on the cold end for a few reversals. This method results in changing the conditions but in exactly the opposite way from what is most efficient. It does not heat up greatly the cold end but it quickly cools down the hot end to balance the colder end. That this must be so may be easily seen when it is remembered that the flame temperature is a product of the speed of combustion, and that the speed of combustion decreases as the temperature of the preheated air for combustion decreases. These facts must follow because immediately upon reversing, the cold air entering the checker chamber is heated up, which results in a cooling down of the checker chamber. If the cold air continues passing through the same checker chamber long enough, it may cool the chamber down sufficiently so that the air is not preheated high enough to give rapid combustion, and the flame will increase in length until it becomes equal in length to the flame obtained on the cold end.

It is impossible to reverse the regenerative system on a time basis method which is most efficient to take care of the changing conditions encountered in operation . The most efficient method is to have the reversals controlled from the temperature conditions within the systems themselves. It should function efficiently during the operating irregularities and keep in step with the changing heating conditions as the furnace becomes older. In other words, it should be able to balance an unbalanced regenerative system, maintain it in balance, and furnish the highest temperature of preheat during the furnace operation.

Extensive studies have been carried on during the past two years on a 100 ton, basic, open hearth furnace to develop the best method of operating the regenerative system, to definitely control the temperature cycle of preheat and thus to control the combustion rate and flame temperatures in the furnace. In others words, fuel efficiency and increased production per unit were the basic ideas underlying these studies. Another phase of the study was to determine whether the control method could be operated more successfully automatically or manually. Exact data was tabulated for several hundred heats.

The following methods were investigated:

1. Reversals were made at constant time intervals.

2. Reversals were made on a high and low temperature limit in
   (a) The flues adjacent to the cold end of the checker chambers.
   (b) In the checker chambers. Both bare and protected couples were used in these studies.
3. Reversals were made from a temperature difference in opposite cool ends of the checker chambers, using chromel alumel thermocouples in porcelain protection tubes.
4. Reversals were made from a temperature difference of the checker brick surface in the hottest section of the checker chamber on opposite ends of the system using fixed focus radiation pyrometers sighted on checker tiles placed on top of the checker brick.
5. Reversals from actual air preheat temperatures determined by aspirating the heated air past the hot junction of a thermocouple located in a water-cooled protection tube.
6. Reversals were made on a temperature difference when a bare thermocouple in the flue was connected in a series with a protected couple in the checker chamber and these opposed to a similar set at the opposite end of the furnace.
7. Reversals were made from
   (a) The difference of the averages of flue temperatures on each end of the furnace.
   (b) The average of the temperature difference of corresponding pairs of thermocouples in the flues. Protected and bare thermocouples were used.

Simultaneous temperature conditions were recorded on pyrometers located as shown in Fig. No. 1. A sample of the actual heating and cooling curves obtained are shown in the accompanying graphs in Fig. No. 2.

The temperature difference method has been developed in conjunction with Mr. J. W. Kinnear, Jr., Assistant Superintendent O. H. No. 3, Carnegie Steel Company, Munhall, Pa., as a result of this study. It consists in locating at least two thermocouples in corresponding locations in the regenerative systems, one on each end of the furnace, and having reversals made when the temperature difference in the control positions reach a predetermined difference. It not

OUTLINE OF OPEN HEARTH FURNACE
SHOWING LOCATIONS FOR THERMOCOUPLES USED
IN TEMPERATURE STUDY.

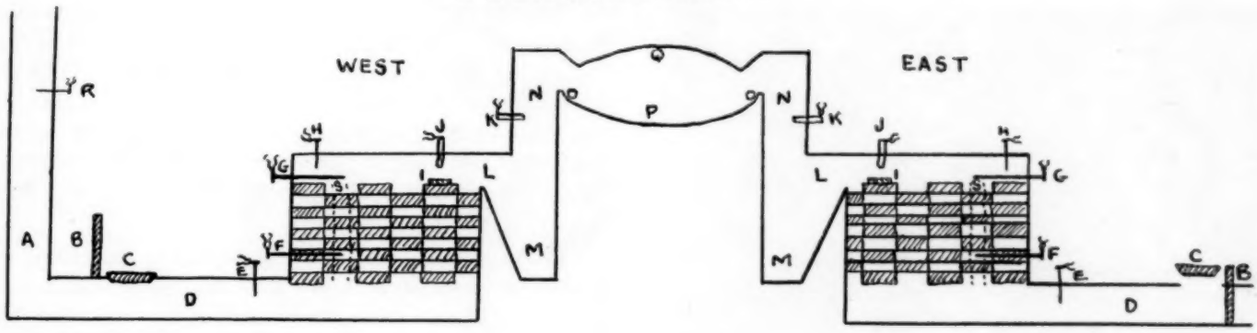


Figure No. 1

A. Stack
B. Reversing Valve
C. Air Lid
D. Air Flue
E. Chromel Alumel Thermocouple (nichrome protection tube) located in Air Flue.
F. Chromel Alumel Thermocouple (nichrome protection tube) hot junction in vertical well "S" through mid line of checker brick, 5 feet from end wall.
G. Chromel Alumel Thermocouple (nichrome protection tube) located just above checker brick through back wall of regenerator chamber.
H. Chromel Alumel Thermocouple ("Fyrstan" protection tube) located through crown of regenerator 3 feet from end wall.
I. Fire clay tile in focus of radiation pyrometer.
J. Fixed Focus Radiation Pyrometer in water cooled jacket focused on tile "I"
K. " " " " " " " " " " uptake brick surface.
L. Fan Tail
M. Slag Pocket
N. Port
O. Burner
P. Bath
Q. Roof
R. Bare Chromel Alumel Thermocouple in stack.

only maintains the regenerative systems balanced but it will balance an unbalanced system. It accomplishes this by automatically and continuously changing the reversal interval on the two ends of the furnace in small increments, heating the cold end up to the hot end until the systems become balanced, after which the intervals may or may not be exactly the same time, depending upon which is necessary to maintain the systems in balance. Both ends increase in temperature, thus supplying the highest temperature of preheat under all operating conditions.

The automatic reversing by the temperature difference method does not limit the actual temperatures in the regenerative systems, but keeps them balanced by having the reversals actuated from the temperature conditions within the systems at the time the reversals take place. This continues to build up the heat head in the regenerative systems to the maximum temperature for any given fuel supply, thus securing the highest temperature of preheat, the greatest return of heat into the furnace, and the maximum fuel efficiency. It ties up many variables and thus works with the first helper to produce more efficient operation.

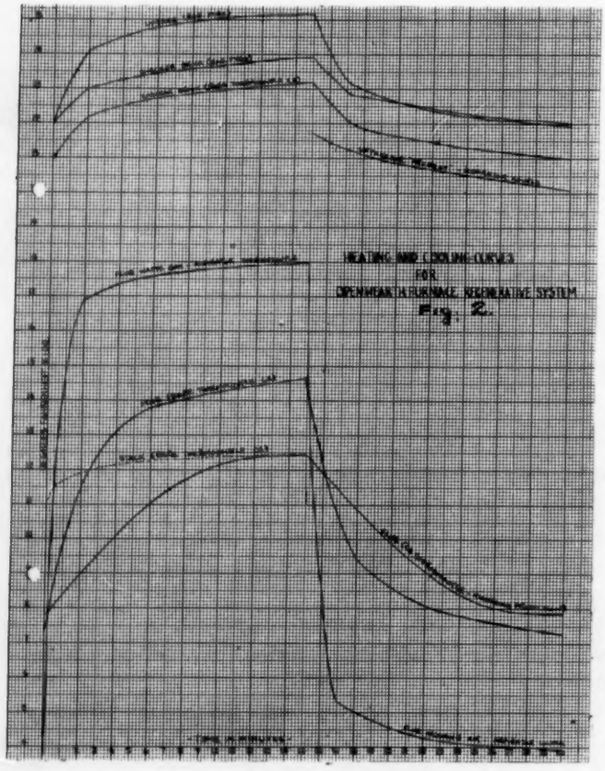


**FIGURE NO. 2**

The fuel regulation, or the proportioning of the fuel and air is left entirely as the responsibility of the first helper. Obviously, during the heat, different stages can be most efficiently carried on under different furnace atmosphere conditions. For instance, the purification of the metal commences at lower temperatures, and speeds up as the temperature increases. So that the air supply should be adjusted not only to burn efficiently the fuel supplied through the burners, but also the fuel (CO) liberated by the chemical reactions taking place in the bath. The rate at which the latter fuel is liberated is a function of the temperature in the bath, and varies throughout the heat. It also varies with individual heats. Thus it is impossible to set a definite air fuel ratio on the burners which is most efficient to take care of the added fuel from the bath. At certain stages in the heat, depending upon how the furnace is running, it may be desirable to have the furnace atmosphere slightly oxidizing, neutral or slightly reducing. The latter is desirable in case a foamy slag exists. If the first helper is qualified to change the set adjustments on the fuel air ratio to meet these conditions obviously he is capable to make the adjustments to obtain the best combustion conditions and fuel economy throughout the heat.

It must be distinctly understood that the temperature difference method of control holds the two control points within definite temperature limits, regardless of what the actual temperature may be. In other words, if the temperature difference limits set on the controller are 150°F., the control points will be held at these limits. It does not matter whether the actual temperature is 1800°F. or 2400°F. The interval between reversals is partially determined by the amount of the temperature difference set on the controller, partially by the combustion conditions and furnace operation and partially by the size and efficiency of the regenerative systems.

These studies also demonstrated the fact that the reversing operations could be made more efficiently automatically than manually. This substantiates the results obtained in an Open Hearth plant in which automatic reversing has been in operation during the past six years. During this time five different furnaces have been under complete automatic reversal control. The fuels used were straight natural gas; straight by-product gas; mixtures of natural gas and by-product gas; mixtures of by-product gas; natural gas and tar, and also mixtures of the gases and oil. During these studies one 100-ton, basic, open hearth furnace has been continuously reversed automatically by the temperature difference method for over three complete campaigns, during which time exact data was tabulated on several hundred heats.

There need be no misconception of the fact that automatic reversing control of open hearth furnaces is today a reality. Although, its use may not be wide spread, it has, nevertheless, reached a point in its development where it cannot be dismissed as simply new and novel. It has passed through the probationary period, demonstrated in service records, and has taken its place as an established method of operation.

# Automatic Combustion Control for Open Hearth Furnaces

By R. W. SIMPSON*

Automatic combustion control for the open hearth furnace is a problem of the application of well known principles of regulation to individual plant operation and in some cases to individual furnace design. It calls for complete co-operation of furnace operators and field engineers for a successful application of the principles.

The system of regulation may be of several types, taking their impetus either from the mechanical principle of flow measurement, or the chemical principle of measuring the oxygen content in the waste gases. The latter is open to some serious objection, inasmuch as the chemical reagents cannot differentiate between regenerative hot air and infiltered cold air, and this infiltration will increase with the life of the furnace, thus decreasing the amount of regenerated air.

The simplest way of applying the mechanical principle of flow measurement is by balancing directly in one regulator, the drop in pressure across an orifice in the fuel line against the drop in pressure across an orifice in the fuel line against the drop in pressure across an orifice in the air line. This regulator is installed in such a way that an increase in fuel flow causes the increased drop in pressure to unbalance the regulator, thereby setting in action a relay which opens a butterfly valve in the air supply to the point where the drop in pressure across the air orifices is again in equilibrium with the fuel line drop. Similarly, a decrease in fuel flow will operate in the opposite direction to decrease the air flow.

This air measurement may be taken from natural draft, or from fan supplied air. By natural draft, the lifting force comes from the difference in temperature in the column of air from the valves to the ports. This pull changes from the beginning to the end of the heats, being least while charging with cold material when the greatest air and fuel supply is needed, and greatest when finishing the heat when minimum fuel and air supply is required. Since capacity requirement comes at the time when the natural draft is least, it is necessary that the height of the column must be great enough to give the desired amount of air during the cold period, meaning deeper checkers than are normally found in open hearth construction. It is therefore advisable to use a fan for supplying the controlled air.

Difference in temperature at the start and at the end of a reversal period give appreciably different lifting forces to the incoming air. This difference in lifting force is of a small order, that is, in small fractions of an inch, but the resistance to the flow through the checkers is of a small order as well, and one is a measurable proportion of the other. Tests of the waste gases on hand controlled operation have shown two per cent (2%) $0_2$ in the products of combustion during the first five minutes of a fifteen minute reversal, .5%—$0_2$ in the second five minutes, and 2%—CO in the final five minutes, showing a difference in the air supplied without control of about 25%. With complete combustion control which means proportionate supply of air to fuel, and damper regulation to minimize infiltration, such tests will show a definite $0_2$ percentage through the reversal period.

The control of combustion in the open hearth is becoming increasingly a more complexed problem, following the use of two or more fuels at the same time. As far as present investigations have gone, it appears that best results are obtained by using different proportions of the fuels at different stages of the heat. It is common practice when using a mixture of coke oven gas and tar to use considerable cold oven gas when melting down, and little or no coke oven gas when finishing, with perhaps the increased amount of tar for the latter stage. To secure anything approaching correct combustion under such operations requires great skill on the part of the operator with hand control, but with automatic control is comparatively easy. All that is necessary is to place a divided or double inlet pipe on the fan, with a butterfly valve in each division and an inlet orifice at the end of each. One butterfly valve will be connected to one regulator, responsive both to the flow of coke oven gas and the inlet air in the same pipe, the other butterfly valve will be connected to a second regulator, responsive both to the flow of tar and the inlet air in its corresponding pipe. Thus will be measured to the furnace the proper air for any proportion of either fuel.

With the increasing use of blast furnace gas mixed with coke oven gas, this system of dual control of the air is in practical operation at three different companies. It has been found desirable in each instance to use larger percentages of coke oven gas in the mixed fuels for melting down, and varying, but in all cases increased percentages of blast furnace gas for refining. It is interesting to note that best results are being obtained at the two plants where special ports have been designed to increase the velocity of the incoming fuels. Further, it can be remarked that with the better port design, there is about 5% increased economy as measured by lower B.T.U. per ton of steel where the gas, as well as the air is regenerated, over the use of cold gas mixture with only regenerated air.

The development of the control for liquid fuels follows along somewhat different lines. An orifice measurement of flow of liquid fuel, while not impossible, has seemed undesirable, due to variations in viscosity of different grades of fuel or different shipments of the same fuel. Consequently, a more accurate system of measurement had to be devised. This liquid fuel system is based on the fact that a positive pressure pump connected in the line with equal pressures at the inlets and outlets of the pump

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will deliver liquid fuel in direct proportion to the speed of the pump. In other words, the pump is used as a meter. Then, by connecting a small fan in line with the pump so that its speed is a multiple of the speed of the pump, the free delivery of air from the fan is a direct measure of the volume of liquid fuel delivered to the furnace. The inlet of this fan is equipped with a suction pipe having an orifice at the end, so that the drop in pressure across this orifice may be used as a measure of the flow of liquid fuel. This drop in pressure is then balanced in a regulator against the drop in pressure across the inlet orifice of the combustion air fan. Thereby, with correct orifice relationship established, the proper air for combustion of any flow of liquid fuel is secured. Such an installation consumes only 2½ amperes for operation at peak demands. A further refinement is to use this indicating measure of liquid fuel flow balanced in a second regulator against the steam flow, thereby establishing definite proportions of steam flow to liquid fuel flow.

The control for producer gas fired furnaces has been worked out along simple lines. The air used at the producers to generate gas is a very definite measure of the amount of gas made, therefore a measure of this air is a definite measure of the gas delivered to the furnace. A common inlet header for the air to the producers is constructed with an orifice at one end. This header connects to each of the steam jet blowers. By manipulating each steam valve, the air is distributed to the two or three producers serving a furnace. The mixture of steam and air is maintained constant by keeping the temperature of the steam and air mix constant. This gives a uniform gas of high quality. The drop in pressure across the inlet header orifice is piped to a regulator and balanced against the combustion air measure, and by keeping these two pressures equal at all times, the proper selection of orifices will assure correct combustion conditions. Where fan blowers are used to supply air for the producers, the arrangement of this system will be very similar.

With proportionate supply of air to fuel established, we must prevent, or at least minimize cold air infiltration. This can be taken care of partially by automatic regulation of the stack damper or induced draft fan. By keeping the hearth of the furnace at as near neutral as possible, infiltered cold air on the incoming end of the furnace with its consequent lowering of flame temperature will be largely eliminated. The selection of the point to control this condition is of vital importance. The pressure in a furnace badly blowing, is by measurement actually very little above atmospheric and with the stack damper wide open, very little below atmospheric. The difference between these two points is a pressure variation of not more than 1/10 of an inch and a novice first helper can keep somewhere in the middle of this position. Consequently, the point at which regulation can be effected, must be found in the hundredths of an inch or closer. To take this point of measurement in the furnace proper with difference in temperature in the furnace body effecting a hot column differential of the same order as the measurement, leads to serious difficulty. But, it has been found that by holding the pressure in the outgoing downtake to the slag pocket constant, the main body of the furnace will be held practically constant. This does not involve two regulators, but only one with a reversing valve taking its motion from the furnace reversing mechanism, which will apply the outgoing downtake pressure to the regulator. This regulator controls the movement of the stack damper or regulates the speed of the induced draft fan.

To completely take care of infiltration, requires a thorough sealing of the entire furnace structure, either with plastic material or encasing in boiler plates. One or the other should be done so as to make as great use as possible of the advantages of combustion control.

The method of burning the fuel has a definite relation to combustion control. In the open hearth, the port of the furnace is the burner and must be so designed as to take advantage of the controlled air. As pointed out above, velocities of the incoming gas and air have a bearing on the efficiency of the combustion, and in general, port design is limited by the necessity of removing greatly increased volumes of hot gases. Successful steps have been made in two plants along somewhat different lines with movable ports in one case and with dampers in the port in another, that tend to give the increased velocities without limitation on the outgoing end. This is good as a first step. However, the melting down of the heat should be accomplished quickly with large volumes of fuel and air, and the refining of the heats can be accomplished with half or less of the amount needed at first. If the velocities are right for the first, they are much too slow for the second with the result that the gas floats in across the roof with damaging effects. So that in port design, again there has to be a general average, rather than the best construction to meet the varying requirements for fuel. A variable port orifice with enlarged cross sections for the larger flows and smaller cross sections for the diminished flows would seem to be needed if best results are to be obtained.

Further, in connection with the velocities of incoming gas and air, they must be proportional to one another so that there will be proper mixing. This is particularly true for furnaces having preheated gas and consequent fixed gas ports. If the air ports are too large in comparison with the gas ports, the air velocity will be too slow and for proper operation of the furnace, excess air will have to be supplied. This excess air cuts down the flame temperature and lowers the efficiency below what should be obtained with the proper amount of air correctly mixed and applied. For furnaces using tar, oil, coke gas or other fuels in a gun type burner, the burner can be pulled back to give quicker mixing or pushed forward to give slower mixing without having to change the air percentage to accomplish this and should in general give greater efficiency.

The fundamental idea back of combustion control is that once having established the proper ratio of air to fuel for a given furnace, such ratio is automatically maintained regardless of rate of firing or of outside conditions. It may be necessary on rebuilding a furnace to re-establish the ratio, for as a rule each rebuild of a furnace acts differently and this may be readily done with a variable orifice on the air inlet, thus changing by a simple lever, the relative areas of the air orifice to fuel orifice and

consequently, the relative proportion of fuel and air as represented by equal pressure drops. However, in regard to rebuilding, it is my idea based on a few cases which have come under my observation, that by combustion control, we have eliminated one of the variables that make furnaces act differently and there will be no further need of resetting the orifice.

Other possible improvements in the open hearth seem to center around a greater recovery of the waste heats. This involves either preheaters of a metallic type, or a better arrangement of checkers for the transfer of heat. In checker development a stove type checker or a three-pass checker in the present chamber areas are possibilities. All of these mean additional resistance to the pulling in by natural draft of the combustion air, as well as the elimination of the waste gases by the stack draft. This leads to forced and induced draft fans. To operate the fans with hand controlled valves, can easily lead to greatly increased fuel figures for the capacity of the fan should be greater than available with natural draft, and an improper setting of the valve will put combustion further out of line. This makes it of even greater advantage to use combustion control.

In conclusion, automatic combustion control will eliminate one of the variables from furnace operation which means fuel economy in amounts that will pay for the installation in a year or less. It means also definite control of the atmosphere of the furnace, which leads to better quality steel. Among other advantages to be obtained are increased production and lessened brick repairs.

# *Discussion of Open Hearth Furnace Control*

By M. GREENBERG*

The problem of Open Hearth Furnace Control is fundamentally no different than the problem of Boiler Furnace Control, and resolves itself into two main divisions; the introduction of the correct amount of air to obtain highest combustion efficiency, and the maintenance of correct draft conditions. We will assume, of course, that the furnace, burners, air ports, etc., are properly designed for burning the fuel that is being used. The matter of maintaining the proper draft conditions is relatively simple and easy, and our major problem is to determine and use the right amount of air for efficiently burning the fuel under various conditions.

The problem of obtaining and maintaining efficient combustion conditions in a boiler furnace has, through many years experience, been quite satisfactorily solved, and it seems only natural to apply the result of our experience with Boiler Furnaces to solving the problem of combustion in Open Hearth Furnaces. There is one fundamental difference between the operation of a boiler furnace and an Open Hearth Furnace and that is, in a Boiler Furnace all of the combustible is introduced by the fuel itself, while in an Open Hearth Furnace a considerable amount of combustible is evolved from the bath; therefore, sufficient air must be supplied not only to burn the fuel introduced into the furnace but also to promote the chemical action of the gases generated in the furnace. The net result though is the same; we want to supply enough air to the furnace to completely oxidize all the available combustible, and no more.

In one way, controlling the amount of air to an Open Hearth Furnace is easier than controlling the air to a boiler in that the air and the fuel supplied to the furnace can actually be measured, while in a (coal fired) boiler it is necessary to measure the products of combustion rather than the air and the amount of steam generated, instead of the fuel. In a gas or oil fired boiler, the fuel and air are sometimes measured. In both cases the products of combustion are analyzed with a hand Orsat to determine when we have obtained the correct combustion conditions. To arrive at the best combustion condition, the amount of air supply is regulated and the stack gases analyzed until all traces of unburned gas have just disappeared. Once we have established the correct relation between the air and fuel, it is then just a matter of adjusting the Air Flow meter so that those desired conditions can be reproduced without having to go to the trouble of making stack gas analyses everytime. The air flow meter is adjusted so that when the correct relation between the air and fuel supply has been attained, the position of the two recording pens coincide on the chart. It should be

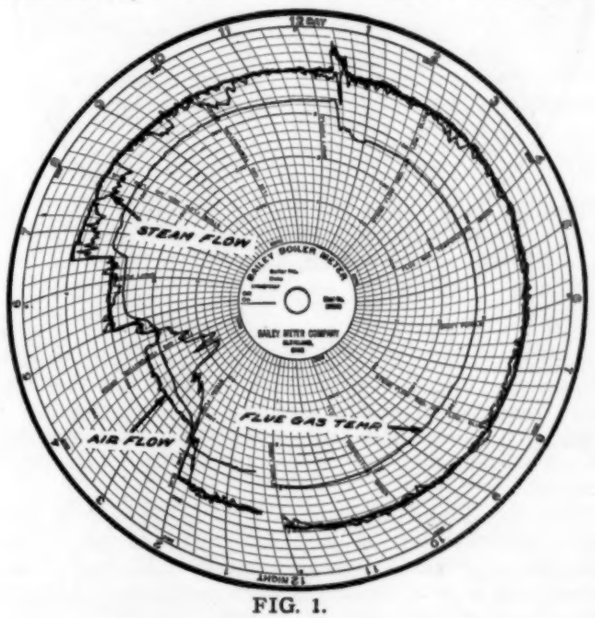


FIG. 1.

remembered that the ratio adjustment is made, not on a theoretical basis but from actual results obtained. This method of guiding the boiler operators has been, almost universally accepted by the large Power Stations in the United States. Knowing now, the conditions we want and having the meters to show

* Pgh. Dist. Mgr., Bailey Meter Company, Cleveland, O.

us when those conditions are attained, we can go about obtaining them either by manually adjusting the air in proportion to the amount of fuel we are using (which can be done quite satisfactorily) or we can apply an automatic control which will relieve the operator of this responsibility, in other words; the meters tell the operators what adjustments to make in order to bring about the correct combustion conditions or, with Automatic Control, they actually operate the fans and dampers, themselves as will be explained.

Fig. No. 1 shows a typical, good, chart from a Boiler Meter. The Air Flow and Steam Flow parts of the meter have been adjusted so that when the correct amount of air is being used, the red air flow pen and the blue steam flow pen coincide. When the air flow pen is above the steam flow pen it shows that too much air is being used for correct combustion conditions and when the air flow pen is below the steam flow pen it shows that an insufficient amount of air is being used. Thus we have an instantaneous guide for combustion efficiency, and all that is necessary is to maintain the two records at the same rating.

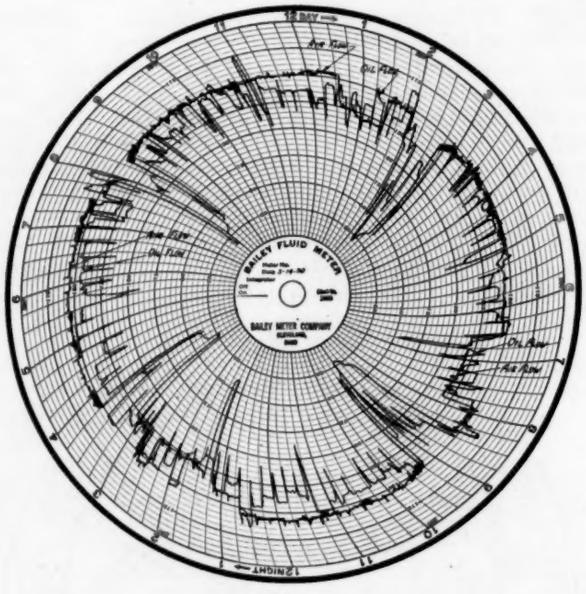


FIG. 2.

Fig. No. 2 shows a chart from the same type of meter that has been applied to an Open Hearth Furnace. The red record shows the fuel and the blue record shows the air that is being supplied. Just as on the Boiler Meter Chart, when the two records coincide, the proportion of air to fuel is correct.

For hand control the ratio meter serves as a guide for good operation; under Automatic Control it takes the place of the human operator and at the same time serves as a check on the operation and on the results obtained from the control.

Fig. No. 3 shows a diagrammatic layout of one type of control that is particularly applicable to open hearth work. The amount of fuel used is controlled manually, depending on the amount of heat desired, and the amount of air is adjusted automatically by the control.

**Description**

The Control consists essentially of a Fuel Meter (gas or oil) an Air Meter, an Oil Pump inside an oil tank and oil piping system, a Pilot Valve and Stabilizer, and a Power Cylinder for operating the Valve in the air line.

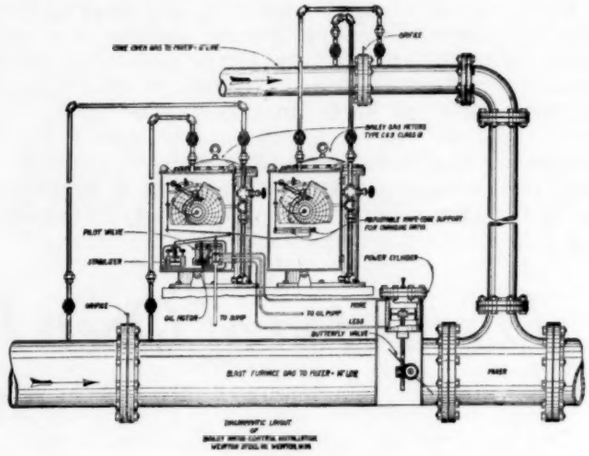

FIG. 3.

In the diagrammatic layout, the left hand meter records air flow, the dependent variable, while the right hand meter records the fuel, the independent variable. That is, the flow of fuel may be varied at will by the operator, and the flow of air will immediately be adjusted by the control in order to maintain the proper mixture of air and fuel.

The meter spindles, which actuate the recording pens, are connected through arms, drop-links, etc., to the link which operates the pilot valve. The pilot assembly consists of a hydraulic motor, oil pressure operated, together with pilot valve, cylinder and geared connection between the hydraulic motor and pilot valve. The hydraulic motor continuously rotates the pilot valve; this rotation reduces to a negligible quantity the frictional resistance offered by the pilot valve to vertical movement by the linkage. The pilot valve itself is essentially a balanced piston valve, having two lands which are of slightly less lengths than the ports which they cover. This slight excess length of port allows a small oil leakage from the pressure supply line (which leads into the cylinder between the pilot lands) into the more and less pressure lines leading to the respective sides of the hydraulic piston of the air regulating valve. This oil leakage insures an equal pressure on the two sides of the hydraulic piston when the butterfly valve controlling air flow is at the correct position with respect to the flow of fuel. This condition of course, exists when the pens are at the same percent of chart and the pilot valve is in the neutral position.

The stabilizer, as its name implies, is a device incorporated in the system to prevent hunting or over travel of the air regulating valve. The mechanism consists of a piston and cylinder, the piston being spring loaded. The piston rod is connected to one end of the link which actuates the pilot valve, and upon any displacement of the pilot valve, the stabilizer immediately tends to return the pilot valve toward the neutral position.

In the right hand meter is shown mounted the

movable fulcrum support of the adjustment device by which the ratio of the air and fuel may be varied. The link pivoted at the fulcrum is slotted, so that the fulcrum can be moved to the right or left by means of the adjusting screw. The screw is turned clockwise and the fulcrum moved to the left in order to increase the percentage of air used.

The oil pressure for the system, is supplied by a small globe rotary pump, electric motor driven. The oil supply for the pump is taken from the oil reservoir, and upon leaving the pump, passes through the de-aerator and oil filter. The supply line then leads from the filter to the pilot valve. A second line, in which is installed a relief valve, leads from the de-aerator back to the oil reservoir. The adjustment of this relief valve determines the oil pressure which is maintained by the pump. The oil level in the reservoir is indicated by a gage glass mounted on the side.

**Operation**

The operation of the control can probably be best understood by considering a cycle of operation. Let it be assumed that gas fuel is being used at a given rate, and that the ratio of air to fuel is correct; in other words, the pens of the two meters are recording at the same percent of chart. Now, assuming that an increase in fuel is required, the first helper opens the fuel valve which results in the pen recording the fuel flow to rise on the meter chart. It will be seen that the rise of the fuel flow recording pen results in the arm supporting the right-hand droplink being lowered. This droplink in turn lowers the left end of the link pivoted at the fulcrum, the position of the fulcrum determining the ratio adjustment. The right end of the pivoted link having been raised results in a rise of the right-hand end of the main cross link, which in turn raises the pilot valve a small amount.

Upon the upward movement of the pilot valve, oil is admitted to the "more" oil line leading from the pilot valve to the upper side of the hydraulic piston and cylinder. The oil admitted above the piston moves the piston and rack downward and opens the butterfly valve a certain amount, depending on the initial amount of rise of the fuel flow recording pen.

The butterfly valve, having been opened, allows a sufficient increase in flow of air to maintain the proper relation between the fuel and air, and the left-hand meter pen recording the flow of air rises on the chart. The rise of this pen lowers the droplink of the left hand meter, and the pilot valve is moved back to the neutral position as a result of the lowering of the left end of the main cross link.

To bring out the action of the stabilizer from the foregoing discussion; when the pilot valve was lifted to admit oil to the "more" line leading to the hydraulic cylinder, this increased pressure in the more line was also communicated through piping to the top of the piston of the stabilizer, which caused the stabilizer piston to move downward against the action of the springs ,and move the left end of the link connecting the stabilizer and pilot valve down with it; the amount of movement depending on the differential oil pressure and the stiffness of the stabilizer springs. This downward motion of the link end replaced the pilot valve a certain distance toward its neutral; and in any change the stabilizer tends to work in a direction to as to replace the pilot in order to prevent hunting and overtravel of the butterfly valve, as before mentioned.

The same type of control is used for mixing two gases in any desired proportion. The two controls can be combined so that the two gases are first mixed to a desired proportion then the proportion of air to the mixed gases is controlled. To go a step farther (where a combination of oil and gas is used) the amount of gas, the amount of oil and the amount of steam for atomizing the oil, can be controlled and then the proper amount of air for the combustion of the combination fuels can be supplied. There is practically no limit to the number of elements that can be controlled.

There is one feature of the combustion control that cannot be made automatic, and that is the adjustment for quickly increasing the amount of air supply to burn the gases evolved when the bath begins to boil. As soon as the boiling commences, the first helper must throw over an auxiliary lever or switch which will instantaneously increase the air the desired amount. The switch can be made three-way; for a light, a medium, and a heavy boil, increasing the air, say, 30%, 40% and 50% respectively, or any other proportion that is found desirable. After the bath has stopped boiling, the switch is thrown back for standard conditions.

Controlling the draft is a much more simple problem than controlling the combustion, but the mechanism used is exactly the same. It is a matter of balancing the induced draft fan or damper against the forced draft fan to obtain the desired furnace draft. Another feature that can be incorporated is to vary the furnace draft for different conditions of the bath.

No control will operate satisfactory unless it has complete control of all the air admitted to the furnace; that means that the furnace and checkers must be made tight by being properly insulated and preferably metal sheathed. I believe also, that the general experience has been that to be able to make a satisfactory control installation, the furnace must have a forced draft air supply.

Besides the meters for recording the air and fuel, and the automatic control, it is often desirable to have various draft indications, such as draft at the checkers, draft at the uptake, stack draft, etc. Recording inlet and outlet air temperatures of the checker and regenerators; inlet and outlet gas temperatures; recording or indicating air and gas pressures; are all coming into wider and wider use. The application of draft gages to furnaces is more extensive at present than the application of meters and control, and it is a step in the right direction. The rest will follow as the advantage and the economic worth of their use is realized.

# *Machine Control of Combustion in Metallurgical Furnaces of the Iron and Steel Industry*

By J. F. SHADGEN*

A survey of the realities and an appreciation of the possibilities.

**Introduction**

Looking as an outsider on the many processes that comprise the great iron and steel industry, it is amazing to note the vital part that HEAT (its generation and absorption) plays everywhere in each department in all divisions from the blast furnaces to the finishing mills.

Most all steps in the making and transformation of iron and steel produces from the ore to the nail, involve **"high temperatures"** and require close study of the fuel technique as a collateral to the metallurgical and chemical fundamental principles.

The various steps have to be reviewed and analysed individually to get a real picture of the cardinal importance of the fuel item, both as to cost and influence on the quality of the final products. The metallurgical furnaces can be subdivided into six groups:

| | | | |
|---|---|---|---|
| A | (1) | The blast furnaces | (2400-2800) |
| B | (2) | The open hearth furnaces | (2900°F) |
| C | (3) | The soaking pits and furnaces | (2300°F) |
| | (4) | The reheating furnaces and kindred | (2200°F) |
| | (5) | The annealing furnaces and kindred | (1500°F) |
| | (6) | The low temperature ovens | ( 750°F) |

These subdivisions are not arbitrary, but in line with the three major divisions of the art: Making of pig iron, making of steel and shaping of final product (#3, 4, 5 and 6) belong really to the rolling mill division.

These various groups of course vary in design and purpose according to the metallurgical, fundamental reactions upon which they are based, but above all, their individual units vary in size according to the economic handling of all the material involved. Blast furnaces are large because the auxiliary equipment, to be economical, must be of gigantic size, while rolling mill furnaces can be made almost any size to accommodate local condition and market consideration.

The following analysis has mostly the fuel aspect in mind and its relationship to greater process economy and plant efficiency:

I—The **blast furnaces** are large shaft type furnaces in which the raw materials, ore and flux, are mixed with the fuel, coke, and charged through the top and gradually reach the reduction and melting zone at the bottom, where preheated air is blown under pressure into the hearth. The metallurgical result, reduction of the oxides and melting of the metal, achieved through the combustion of the fuel and the contact reactions, is Pig Iron, a eutectic mixture of Fe with some 3—4% C that is fluid at relatively low temperatures varying between 2100°F-2200°F.

This process requires, roughly, an average of one ton of coke per ton of pig iron produced; the nature of the ore and richness of the burden, of course, determines this factor as well as the quality of the pig made. Statistics show that the fuel cost constitutes about ½ of the transformation cost (50%). There is a latitude in this figure on account of the value of the blast furnace gas (a valuable by-product).

Combustion of the coke fuel is therefore of paramount importance. The daily production capacity varying from small unit of 300 tons to 800-1000 tons in the large plants, add considerably to the practical difficulties. Responsibilities became very severe and conservatism is the rule in the blast furnace game. This condition is further complicated by the divided problems and increases of turbo blower operation and stove design, and the great difficulty of appraising results in the absence of positive test data.

Hence, the control of combustion of the fuel in blast furnaces to meet the practical operating demands, becomes an engineering problem of first magnitude requiring, above all, Goodwill of all parties concerned and furthermore, the spirit of cooperation between department heads, between designers and operators and with the active mediator of regulation experts, who so far, have never appeared in the picture. Here is a problem that remains a hope until the future ripens the plant conditions for further development.

II—**The Open Hearth Furnace**—The limited practical applications of pig iron, due to its physical properties, is the cause of the second steps of the industry; the transformation of pig iron into steel or iron. Metallurgically, this operation means purification, reduction of the carbon content from 3—4% down to 1—0.1% with simultaneous elimination of Si, Mn., P. and S. and perhaps additions of Ni., Va., Mo. etc. Pyrotechnically, the operation means raising the melting point from 2100°F-2300°F pig iron to 2600°F-2900°F of iron, steel and alloys. This requires the hottest flame temperatures known to industry.

Real ingenunity could only solve that problem. Bessemer solved it first in a brilliant way, later amplified by Thomal in the acid and basic converters without fuel additions. But limitation of quality demanded a different solution. The open hearth furnace furnished the tool for the well known Siemens-Martin process pioneered by these outstanding engineers and time demonstrated its universal adaptability to the whole iron and steel field.

The open hearth furnace looks back to half a century of development without radical changes, its future looks bright as no real competitor it in sight. The size of unit has grown

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from the early minature models of 5 tons and 10 tons to the big modern 250-325 ton furnaces. The average size though is between 80 tons and 150 tons.

The daily production has risen to a maximum of 500 ton representing a dollar value of some ten thousand dollars ($10,000)). Average capacitys though, vary between 150-300 tons per twenty-four hours or, if you prefer, 5,000 to 10,000 tons per month. Furnace campaign average 100-150 days. The fuel used in the transformation process of the open hearth furnace varies widely. Solid fuel is practically impossible although several plants are still operating with pulverized fuel. Producer gas, oils, tars, natural gas, coke oven gas, blast furnace gas and mixed gases are the major supply forms of heat.

Average fuel figures are 5,000,000—6,000,000 B.T.U. per ton, meaning 450-550 lbs. of coal, 5,000-6,000 cu. ft, of natural gas, 30-40 gallons of oil per ton of finished ingots. The fuel cost constitutes about one-third of the transformation cost, dividing the honors with the labor item and furnace repair item. These averages of course, fluctuate widely among the leading districts and among the various plants of each district.

The fuel item is not only important on account of its own cost, but on account of its influence of the quality of the steel made. The nature of the flame, its shape and development, have a bearing on the reactions that take place. You all know the practical difficulties that it is futile to rub it in here.

The conditions being what they are, it follows that the question of combustion control is very vital. It is astonishing, in view of the great reward, how little has been done towards scientific research and positive coordination of the many variables that enter into consideration and it remains to machine control of combustion to fill this gap at least in part.

III—**Iron and steel ingots,** as they are cast in the steel mill, have no practical use. They are an intermediate product that requires transformation into final shapes, varying from wire and nail to column and girders.

Ingots vary in shape, size and weight from 500 lbs. to 10,000 lbs. or more. To be fit for the rolling mill, hammer or press, the temperature of the metal must be uniform.

The **soaking pits on soaking furnaces** are built to equalize the temperature of the freshly cast ingots. This is done by soaking the metal some 1—3 or 4 hours in refractory chambers, usually provided with an outside supply of heat. The melting temperature of the metal is lowered from 2600-2800°F to the plastic zone 2100-2300° F. The outside heat requirements are small if hot ingots are charged. Modern pits use less than 50 lbs. of coal per ton charged. Average figure fluctuates from 60-120 lbs.

Flame control is important on account of the direct contact with the metal to be soaked and the necessity to avoid scale formation, hot spot and skin trouble.

The output per furnace is determined by number of holes, size of holes, etc., but above all, by capacity of blooming mill—average installation 800—1500 tons per day.

The value of the control of combustion is recognized by operators and appreciated by designers and machine control is looked upon as the next step in the development to make further economies possible.

IV—**Heating furnaces** are used in rolling mills to reheat the intermediate shapes (billets, bars, pairs, sheet bars, slabs, rounds, etc.) and to bring their temperature up to plastic zone 2100°F to 2300°F where resistance to rolling is minimum. These furnaces may be charged with cold, semi-hot or hot raw product. Their hourly capacity varies with the nature and shape of product. Some continuous billet furnaces have an hourly production of 50-100 ton but normal units are from 5-20 tons.

To heat 100 lbs. of iron or steel from cold temperature up to 2300°F, some 90,000 B.T.U. are required. Expressed in fuel, this means about 3 lbs. of coal at 13,500 B.T.U. per lb. about 0.25 gallon of oil at 150,000 B.T.U. per gal. or 80 cu. ft. of coke oven gas at 500 B.T.U. per cu. ft. or 40 cu. ft. of natural gas at 1000 B.T.U. per cu. ft. or 300 cu. ft. of producer gas at 135 B.T.U. per cu. ft. Using the ton of 2000 lb. as a basis, the figures are 800,000 B.T.U., or 60 lbs. of coal; 5 gal. of oil 1600 cu. ft. of coke oven gas, 800 cu. ft. of natural gas and 6000 cu. ft. of producer gas. These figures are handy for reference and easy comparison.

Fuel economies vary and efficiency fluctuates between 20 and 75%. The latter figure being the rare exception. Average 30-50%—billet furnaces 80-100 lbs. of coal, slab furnaces 100-150 lbs., sheet mill furnaces 200-350 lbs. and more in forge furnaces on account of the intermittent operation.

Special attention is called to the fact that the maintenance of the proper metal temperatures in the plastic zone is important to reduce power and wear at the rolling mills. 2200-2300° is desired not 2000-2100°.

Efficiency is slogan in modern gas fired furnaces, especially in the large size and combustion control has been applied and is looked upon as an accurate tool for best operating results.

V—The **second group of heating furnaces** deals more with the finished product than with the raw material. The temperatures are relatively low in the 1200°-1700°F where the allotropic changes of iron take place. The trade usually call these furnaces annealing, tempering or normalizing, depending on their function. Their operation requires, besides a definite temperature, a "time factor" similar to the soaking pits. Operating intermittent in all car or box type furnaces, continuous in the kiln type. Fuel important, but general figures of little value except if all details are given.

VI—The **last group of furnaces** are the low temperature ovens used for coating process or special treatments. Zinc melts at 790°F—lead at

625°F and tin at 450°F. Nitriding is usually done at 850°F, never over 950°F. All these furnaces are of small capacity and special. Their use is limited to specialty shops and mention is made here only to complete the survey of the whole industry.

This summary expose clearly demonstrates the importance of fuel item in the various process and progressive steps of the entire iron and steel industry. Fuel affects the economies of each process and contributes to the value of the final material. Fuel means heat and heat means combustion, which can only be translated into a practical reality by **efficient control.** The time of hand control with its opinions, guesses and prejudices, is to give way to **machine** control of combustion based on facts, measurement and accurate test data.

The outstanding field of application is unquestionably the open hearth furnace. The units are fairly large, the operation is intricate and complex. The field is virgin because furnace design is empirical throughout and operation is governed by rule of thumb.

If we analyse the installation of a new furnace and face both design and operation squarely, we can discern two major subdivisions of the problem—the static phase and the dynamic phase.

The **static phase** means construction of the furnace, its frame, its brick work, the hearth, flues, checkers and stack. This is very tangible, can be put in blue prints, estimated and definitely planned. It is planned by designer and constructors who leave as soon as the job is done.

The **dynamic phase** starts with operation and comprises everything that moves, that flows—the charge, the additions, the molten metal, the slag, the fuel, the air and the waste gases.

The dynamic must create the results and pay their way, yet today, too great emphasis is laid on the static part that offers, shackled down, the freedom of operation. As long as furnaces are sold and installed on the basis of blue prints, brick and refractory designs, the dynamic phase will be limited. Furnaces are shells that govern the flow of gases, that vary in intensity of reaction and in effectiveness.

Hence, flow charts of a furnace seem to be a fundamental necessity rather than a casual accessory. Flow charts will give a tone picture of the quantities of fuel and air handled, of the volume of gases removed and their relationship to output of metal produced. Flow charts will determine the velocities at the various parts of the furnace, the shape and size of checkers and frost area. Flow charts will also fix definitely, the points of control and correction that govern the quantities of gases and their ratios.

It follows that flow charts should be the foundation and not the appendix to furnace design and operation.

Regulation and control can only be based on these basic considerations as only flow is being controlled.

The first steps have been made and regulating devices have been adapted to a number of existing furnaces. The operating results covering several campaigns and a number of furnaces located in different plants confirm the expectations and above all, check and double check the logic conclusion drawn above.

The results and performance due to the application of machine control to open hearth furnaces can be summarized as follows:

(a) Increase in production.
(b) Decrease in fuel consumption per ton.
(c) Longer life of furnace.
(d) Better and easier metallurgical operation.

These results are similar to the experience in boiler plants where, during the past ten years, machine control of combustion has demonstrated its economic value.

From the development, so far, the following directions can be drawn:

(1) **Complete Machine Control is Essential:** Part control did not work out as well as expected. This is obvious because complete control avoids alibis, splitting of responsibilities and offers a clean cut job.

(2) **Engineering Adaptation is Necessary:** As most of furnaces were existing only limited changes were possible and the burden of the success fell on the shoulders of the engineers, installing the control equipment. This requires engineers, surveys and analysis of the local condition to adapt developed machines to special circumstances.

(3) **Service and Education of Personnel is Desirable:** After the installation is completed, the operators must be familiarized with the new equipment and taught to use it to best advantage. Heaters and melters should be included in those teaching courses.

These three directives require the concerted effort of a trained organization that specializes in that kind of work. It is obvious that an individual alone, no matter how willing, cannot render these services.

(4) **Machine Control Requires Real Regulators:** A regulator is a dynamic balancing system that transforms a small sensitive disturbance into a powerful effort operating a damper or valve that corrects for the disturbance. Hence, a regulator is a fully developed machine that looks back on years of research and development work.

(5) **Machine Control System Requires a Logical Idea** in harmony with the management principles and plant organization.

These directives will guide you in the study of the problem and help you to co-operate with responsible manufacturers in the choice and installation of the proper control system. It can be safely said at present that liberal returns await those who install the right equipment and use it intelligently as an accurate and handy tool.

# Open Hearth Furnace Control

## Discussion

*R. S. Higgins, Engineer, Shallcross Control Systems Company, Chicago, Ill.*

*G. D. Conlee, Chief Engineer, Republic Flow Meters Company, Chicago, Ill.*

*R. D. Bean, Manager, Engineering Development, Brown Instrument Company, Philadelphia, Pa.*

*J. F. Shadgen, Combustion Engineer, Smoot Engineering Corporation, New York, N. Y.*

*E. A. Brown, Jr., Assistant to Chief Mechanical Engineer, Carnegie Steel Company, Munhall, Pa.*

*F. E. Leahy, Combustion Engineer, Youngstown Sheet & Tube Company, Youngstown, O.*

*R. M. Walker, Engineer, The Bristol Company, Pittsburgh, Pa.*

*M. Greenberg, Pittsburgh District Manager, Bailey Meter Company, Cleveland, Ohio.*

*J. W. Kinnear, Jr., Assistant Superintendent Open Hearth No. 3, Carnegie Steel Co., Munhall, Pa.*

*H. K. Miller, Combustion Engineer, Bethlehem Steel Company, Steelton, Pa.*

*R. D. Abbiss, Assistant Chief Engineer, Edgar Thomson Plant, Carnegie Steel Company, Braddock, Pa.*

*M. J. Bradley, Engineer, Leeds & Northup Company, Philadelphia, Pa.*

*Arthur W. Steed, Superintendent of Maintenance; American Rolling Mill Co., Middletown, O.*

**R. S. Higgins:** After listening to Mr. Simpson and Mr. Bradley and Mr. Shadgen, there isn't much left to speak upon.

I just want to say a few words in regard to open hearth furnace control. Our experience, like the rest of the concerns, has been more or less limited because of the newness of the art. We have found that a complete control system has divided itself into two parts primarily. In one is the control of combustion, and the other a control of reversals. In the control of combustion of the open hearth, there are two systems that can be pursued. They have been mentioned before by Mr. Simpson. One is the ratioing of the air to the fuel by measurement of the excess oxygen in the waste gases. The other is the ratioing of the air to the fuel by balancing differentials in flows. But in either event, the furnace atmosphere is very important. We have found on furnaces where we have been controlling the ratio of air to the fuel that waste gas analyses vary at simultaneous readings from as high as .5 per cent oxygen to 6.8 per cent oxygen. This has been caused directly by the condition of the furnace atmosphere or the amount of draft in the furnace.

When the furnace draft is in excess the front doors are pulling in a lot of outside air which cannot be controlled by a ratio control, and when the furnace draft is controlled it is possible to regulate the amount of excess air flowing into the furnace proper, thereby distributing the gases of combustion across the furnace more evenly, and getting a more representative gas analysis going into the flue.

This morning in the discussion of the modern industrial furnaces, we found a decided trend towards one-way continuous furnaces employing recuperation instead of regeneration. We wonder if the time isn't here to consider open hearth furnaces fired one way. Most of the control problems in the open hearth arise from the reversing of the open hearth furnace, which makes it very difficult to get a favorable heat balance. Of course the temperatures involved in the recuperation or regeneration on open hearth furnaces prohibit the use of ordinary air pre-heaters or fuel pre-heaters, but we think that the time is near when such a design will be accepted and will prove out to be quite an advantage over the present type of reversing furnace.

During the operation of a furnace it is often necessary to change the ratio of air to fuel because of the gases being generated in the bath itself. This can be done only by checking the waste gas analysis very frequently, after each reversal. We have found it necessary at certain times to increase the percentage of total air in some cases to 20 per cent in excess of the usual or normal amount of air being used by the gases as fuels themselves.

**G. D. Conlee:** Our company has no system of open hearth furnace operation to offer. We don't feel that we know anywhere near as much about the subject as the operating and designing engineers of the various steel companies.

Our aim has always been the making of measuring instruments and we have always kept close to that line of endeavor. From time to time various engineers have felt the urge and we have put in meters to measure air, where air under pressure was supplied to furnaces; meters to measure natural gas, cokeoven gas, and meters to measure oil and tar. The latter two problems, however, are rather difficult. It is practical to measure fuel oil as supplied to open hearth furnaces. There is some uncertainty about the accuracy of oil meters as direct measuring devices, but they are certain for control instruments, that is, the same amount of oil will give the same reading day after day, and that seems to be a very important point in the control and operation of open hearth furnaces.

It is difficult, I believe, for any operator to determine, without some sort of an indicating device, when a constant supply of fuel to an open hearth furnace is being maintained, and it appears that economy in operation depends upon a uniform condition, or perhaps we had better say a uniform rate of combustion, that is, oil or fuel fed at a uniform rate for an hour or more until for reasonable furnace operation, the rate of heat supply is to be changed. Oil meters work in very well and seem to fit into the operation in a very satisfactory manner.

At the present time there is a good deal of tar being burned in open hearth furnaces. We have one

experimental installation now in operation and are learning a whole lot of things about measuring tar. As I mentioned before, tar is very difficult to measure, but I believe we have found a satisfactory way of doing it.

Some of our good friends have been interested in the use of $CO_2$ recorders for open hearth furnaces. Theoretically, I believe the measurement of $CO_2$ in the outlet gases is not a perfect measure of combustion because of the varying percentage of $CO_2$ given up by the bath. However, as one gentleman told me, high $CO_2$ usually indicates high efficiency of combustion, and with some sort of a device to check up on varying percentages of $CO_2$, it is possible to maintain a satisfactory high combustion efficiency. Incidently, the cost of installation of the flow meters of various kinds is so small compared with the fuel cost, that I am convinced that they will be used very generally in the future.

In connection with what Mr. Shadgen said about measurement of producer gas, Mr. Leahy worked out a system some time ago whereby steam supplied to gas producers gave a very fair indication of the amount of gas being generated and passed on to the open hearth furnace. I think the arrangement has worked very well in his plant.

It is my belief that in the next five years, there will be many changes in ideas on combustion control for open hearth furnaces. At present there is no well established practice and many changes and developments may be expected in the future.

**R. D. Bean:** Gentlemen, most of this discussion has been along the lines of combustion control and efficiency. Our company has not up to the present time gone into that phase of the question. We supply a broad line of measuring instruments and it is rather gratifying to see that during the past two or three years there are a great many instruments being used on open hearth furnaces where they didn't appear before. Mr. Conlee has just mentioned the application of flow meters to the measurement of tar and gas. We have also had occasion to supply such instruments in quite a few installations.

To assist in the study of the problem along the lines of temperature measurement, we have had occasion to do some experimenting with the application of thermocouples. Generally speaking, it is a difficult problem to install thermocouples at those locations where you are most interested in knowing the temperature. You have to go back a way from the hearth itself to measure temperatures which are relative and, you hope, sufficiently proportionate to the actual temperatures that you want to get. These relative temperatures have proved to be suitable as a guide for the control of checker reversals.

It occurs to me in listening to these discussions—and I might remark that we ourselves don't pretend to know very much about open hearth combustion control—that one of the problems is in the determination of excess oxygen. I would like to ask Mr. Shadgen, while I am here, whether there isn't on the market today any suitable device for indicating the hearth. Would not that be a pretty direct way of checking whether or not you are supplying the proper ratio of fuel and air?

**J. F. Shadgen:** Unquestionably it is, but I would like to meet the man who develops the instrument.

Oxygen content of the flue gas is the correct measure of the excess air, as it will be independent of the gases given up by the bath. But up to now to measure oxygen we had to first eliminate the $CO_2$, then cut out the CO, then measure the oxygen by differential, methods which meant we were about ten to twelve minutes late. What is the use of catching a train after that? You are always ten minutes late.

**E. A. Brown, Jr.:** It just occurred to me that that was the ultimate result you are trying to find. Whether it is possible to develop such an instrument I am not able to say.

**J. F. Shadgen:** I would like to meet the man who does and shake hands with him.

**R. D. Bean:** We are doing a little development work along the lines of analyzing flames, and there seems to be some possibility of working out something along that line. Of course, we also supply $CO_2$ instruments that meet with a reasonable amount of success if you can get clean gas to them. But most of the people I have talked with are pretty unanimous in the opinion that it is an extremely difficult thing to attempt to take $CO_2$ samples from the particular portion of the hearth that you are actually interested in; that the high temperatures and slagging action make it impossible to make a sample tubing installation. As far as I know there are no real applications of it.

**J. F. Shadgen:** The difficulty lays not in the $CO_2$ machine, gentlemen, but in the filter, and the approach to the $CO_2$ machine. The $CO_2$ machines are all good. In the laboratory they work perfectly, but try to make one work 365 days a year!

**R. D. Bean:** I would like to ask Mr. Shadgen this. In the line of development of an oxygen recorder, assuming that you could get an indication of change in oxygen content, possibly one minute after it occurred at the hearth itself, how far behind are you in the process of changing your fuel ratio?

**J. F. Shadgen:** Very good. That would be satisfactory from the operating point of view.

**Roy M. Walker:** For regenerative furnaces, the Bristol Company have various instruments, suitable for automatic control; or manual control directed by signal lights; either for operation by time cycles or temperature cycles. We have furnished these for both glass and open hearth furnaces.

We also like to call attention to our pressure controller and draft controller for very low pressures, like a fraction of an inch head of water pressure or vacuum. This controller is a special help in open hearth operation.

As your gas producers are usually closely connected with the open hearth, some of our recent installations of controllers on gas machines should be of interest. We are controlling the height of the fuel bed in the producer gas machine. We are controlling the pressure of the gas from the gas producer to the open hearth. We are also controlling the temperature of the air and steam mixture under the fuel bed of the gas producer, keeping this temperature as low as practical without permitting the formation of clinkers.

**M. Greenberg:** I am sorry Mr. Shadgen walked out just then. I don't know whether he did it be-

cause I was coming up to talk or not. In regard to the question the gentleman from Brown Instrument Company brought up as to whether there was such a thing as an excess air meter, I think Mr. Shadgen has heard of the Bailey Air-Flow Steam-Flow Meter, and a good many of the rest of you have, too. We don't claim that is a perfect device, but it serves pretty well, especially the power plant industry.

Another point I might mention is that Mr. Conlee said something about the highest $CO_2$ giving the best efficiency. I don't think that is quite so. Probably Mr. Conlee didn't mean it that way because there is such a thing as having too high $CO_2$ for efficient combustion. That applies both to a boiler furnace and an open hearth furnace, I believe.

**E. A. Brown, Jr.:** This is a subject which I would rather sit around a table with four or five good men and argue about rather than speak here.

With no attempt to slight the other speakers, I would like to confine my remarks to Mr. Shadgen's paper, because it conforms so much with my own attitude in the matter. I especially like his attitude in regard to his method of approach of the subject, by modestly admitting there is so much that has to be done in the way of determining the cause before we approach the application.

Combustion engineering, as at present technically practiced, is so young an art that most of us present can go back to the early days of it. So if we speak of any past mistakes we are speaking of our own mistakes, which is no reflection on anyone who has gone before us. But I think there has been a lot of false work done that we have to live down before we can get the most out of the Open Hearth Control proposition.

We all know that in recent years we have been shown the folly of some of our past work. I might mention measurement of temperature in the flue. My own work goes back to nineteen years, and it was only two years ago that I realized a lot of that work, except from a comparative standpoint, was erroneous.

I can also refer to two or three well known treatises or Open Hearth tests where port analyses were not even made, or draft drops systematically determined, let alone tying these up with flow volume figures. Yet we tried to make interpretations on the basis of those data. It was all good work but then more or less pioneering. But now I believe we are getting much farther ahead in the art, not so much by what we have actually learned, for so much is yet to be known, but by advancing above zero, you might say, for I believe we have had first to knock down a lot of our old ideas which had jumped us to conclusions too quickly.

Air-infiltration—we always realized what that meant, but I don't think we ever realized it to the extent that we do today, or the extent to which we would do well to regard it. Until that is under control, automatic control of furnaces is a hard proposition.

At this meeting, like the one at the Engineering Society of Western Pennsylvania, where Mr. Chandler read a paper, I am forced to take exception to comparing an Open Hearth and its combustion problem to anything like a boiler or blast furnace stove. It is an entirely different proposition. I don't think there is any comparison. The fact is, if you think back in the scheduling of your work in combustion engineering, the natural thing to do is to pick the work that is the most attractive or the one which has the most returns with the least expenditure of time and money. The result is that combustion engineers have stuck with boilers until I think the work on them is at quite an advanced state.

The same thing applies to blast furnace stoves. They have been, as we see them now, fairly simple problems, mainly because air-infiltration could be controlled. The heating furnaces we heard about this morning are also, I believe, in a much advanced state in the last few years, through improvements in the continuous furnace, the application of recuperators and preheaters, etc. While we are making lots of steel and making it cheaply, I think we have permitted that problem to go last for the simple reason that it has been a hard nut to crack. I still think it is, but I have all the confidence in the world that real Open Hearth improvement is now under way, starting about four or five years ago. I really think we are now on the eve of big things in the Open Hearth and am most optimistic.

The point I wish to make is that it is going to be done through the approach Mr. Shadgen speaks about, not through any cocksureness of what we have done or what we know, but starting, I believe, at almost zero, after having knocked out a lot of past misconceptions and false conclusions based on far from full facts.

**J. W. Kinnear, Jr.:** Gentlemen, Mr. Bradley asked me to come up here today. I told him I was going to take a back seat and have nothing to say. I did work with Mr. Bradley on automatic reversal and temperature in the checker chambers. Personally, I have nothing to sell. We have used it on four furnaces and we are sold on it.

I would like to explain how we discovered it. When I first went into the open hearth game I went into the labor gang. The superintendent gave me a recording pyrometer. I found that on the furnaces that were running the best in the shop and were paying the men good money, the first helpers were reversing the furnaces and keeping the checkers on each end approximately the same temperature. I found that every first helper regardless of how good he was, would get the furnace occasionally unbalanced. During the start of the week after a shutdown, for the first couple of days the furnaces were unbalanced, and I found that practically every furnace complained of a "cold end." I think the open hearth men know what I mean by that. If you could get the other end to work as good as that end it would be fine. We simply set up a method of keeping the two ends together. We found by studying the temperatures in the best furnaces that they never got beyond a set difference. The two ends kept within a set difference. The temperatures were not true, they were not accurate, but they were entirely relative, however, and we found by running on a set temperature difference we could keep the ends balanced. In six years on this work we have absolutely done away with the could end. If a furnace is charged evenly the lime comes up evenly on both ends. The gas burns the same on both ends. It is not a cure-all, it is not a combustion proposition at all. It simply helps your combustion by giving a maximum supply of pre-heated air.

**F. E. Leahy:** I would like to ask a question. Supposing a furnace has a tendency to run unbalanced, and with your automatic control, is there such a thing that your automatic control would be running continuously on one end, say, from five to six minutes longer than it does on the other end, or is there a tendency to equalize after a time and stay equalized.

**J. W. Kinnear, Jr.:** I don't think any checker chamber is built exactly alike. I think you have all studied your drafts and know that the two ends do not always work alike. There is less pre-heat in one chamber than there is in another. We find that after a furnace becomes unbalanced the cold end will heat up and get a flash heat, and the thermocouples will register that flash heat, but on the reversal, this flash heat disappears very quickly and the control will not stay on that end. This means that the control will gradually bring both checkers up to the same heat balance. On the end furnace in a shop, perhaps where there is a little water getting into one end, or where we have old checker chambers, we will run, for example, ten minutes on one end and twelve minutes on the other. In these cases the control will day in and day out run the furnace a minute or two longer on one end and overcome it. That is purely a fault of construction. We think we have done the best we could along that line. The reversals are not on any time-setting; they won't stay on that. If the first helper changes his fuel and shoots a lot of gas into the furnace it will reverse very fast. If he cuts the gas off, the level of pre-heat is going to drop and the furnace will reverse slower during the cooling down period.

**R. S. Higgins:** Is there any reason why something couldn't be given to a one-way open hearth furnace to get around the temperature differences on the end of reversals, and to stabilize the temperature of fuel and air coming in, rather than going around to take care of the results from the present?

**J. W. Kinnear, Jr.:** I would like to shake the hand of the man who can develop it. The primary trouble as we find it is that the air leaving the checkers, coming up through the checker brick, is around 1800 degrees. The air delivered at the port is around 2100. In a one-way furnace you would loose the heat in the surface of your flues and in your well between the checker brick itself and the bath. That would be about 300 degrees. If you can afford to run at 300 degrees less pre-heat or about 1700° to 1800° air I believe you can run a one-way furnace.

**R. S. Higgins:** Has there ever been any thought given to such a thing?

**J. W. Kinnear, Jr.:** I have seen quite a few designs of it .

**R. S. Higgins:** Has there been any great improvement in open hearth furnace design in the last twenty years or so.

**J. W. Kinnear, Jr.:** The main improvements have been forced upon us by the changing of fuel from natural gas. That ran out and we had to change the furnace to meet that. That and insulation.

**F. E. Leahy:** Some measure of improvement has been made in the Open Hearth. At certain plants they have increased the life of their furnaces from 200 to over 500 heats on the same sized charge. In other words, they have increased the tonnage output, and in many cases reduced their fuel consumption.

Is there anyone here directly connected with the open hearth works who will favor us with a few remarks? If not, I will call on Mr. Harry Miller, Combustion Engineer of the Steelton Plant.

**H. K. Miller:** I don't think I have much to add to the discussion of furnace control. We have one open hearth furnace at Steelton, which has given very satisfactory and economical results. I appreciate that considerable work will be necessary before the difficulties encountered will be entirely eliminated, but with the results so far obtained, we feel we have made a step in the right direction and our plan is to install additional control equipment as fast as conditions permit.

**R. D. Abbiss:** We have one furnace under control and we have done quite a bit of studying on this subject. The study has not proceeded far enough that we can draw any definite conclusions.

**F. E. Leahy:** Is there anyone else who would like to make any general remarks or ask any questions? This is a very interesting subject, one that is quite active in the steel industry, as to the progress that is possible under some suitable form of control. It isn't any controversy with us on whether it will be temperature or flow control. We are willing to have a demonstration of each method. If anyone has developed a control that will function satisfactorily and reliably, I am sure he will find very willing and interested listeners to his description.

We also appreciate that there is a limit to what should be expected even in reliability. We usually make provisions in a case like that so that it will be possible to throw the control at short notice out of operation and return to hand control. The open hearth, as Mr. Brown has said, is a different problem than most of our other heating or metallurgical furnaces. It is a furnace that works at the highest temperatures in the plant. It works at temperatures that are close to the refractory destruction temperature. It has been successfully operated for a good many years without any form of control. This is a problem that many have given quite some study. Combustion control has performed exactly the function it is designed to do, and that is, to maintain the ratio of fuel to air, and yet this may not be exactly the final answer.

The study on that is now being given to the control of flame, and the producing of the proper flame as desired depending on the metallurgical conditions, is still to be worked out. We do not expect any of us that have a very close contact with it, to have a control that will eliminate an intelligent open hearth furnace first helper. That is impossible, and I believe that the appreciation of the value of an intelligent first helper to work with the control and use it as an aid to him rather than a substitute, will bring success to the final solution to this very interesting problem.

Would any of the speakers care to make any concluding remarks? Have you anything further to say Mr. Bradley?

**M. J. Bradley:** I wish to explain that I was anxious to leave early but felt that if there were any questions concerning the Temperature Difference Method as applied in automatically reversing an Open Hearth Furnace, that I would be pleased to explain in further detail. However, Mr. J. W. Kin-

near, Jr., Assistant Superintendent of Open Hearth Department #3 at Homestead Works of the Carnegie Steel Company, where the method was developed, has explained how satisfactorily it has worked during the past four or five years on several Open Hearth Furnaces in that plant.

During the investigation, several methods of controlling and balancing the pre-heat cycle were studied in detail. Several hundred heats were made on a 100 ton Open Hearth Furnace automatically reversed by the Temperature Difference Method. In fact, over 4 complete campaigns were studied and detailed data obtained on temperatures, drafts, production, fuel used, refractories, delays due to hot repairs, and charging, etc., etc., in order to determine the advantages and limitations of the method. It is not necessary to burden you with these details at this time.

The Temperature Difference Method, when the reversals are made automatically, will control the cycle of pre-heated air entering the furnace for combustion, and it will hold the two regenerative systems balanced. The interval between reversals becomes a function of the heat systems and furnace operation. The reversal will be equal on the two ends of the furnace when the systems are balanced, but when they are unbalanced, it varies sufficiently to balance them. Thus the method functions efficiently during the operating irregularities, such as hot repairs, when the heat head in the checker systems may cool down several hundred degrees.

It does not matter whether the actual temperatures are 1800°F. or 2400°F., the operation continues at the greatest efficiency. In fact, it is an advantage to have a new furnace heated up from the start, using the Temperature Difference Method because it keeps the regenerative systems balanced and prevents the refractories from being exposed to excessive temperatures during the heating up period.

**J. F. Shadgen:** I want to make a remark here. We never claim that we sell automatic control. I think that is a bad misnomer. We sell "Machine Control." We substitute to do some operation of the man a machine that has to be set by another man. There is no such thing as automaticity in this world, except day and night, and we are not responsible for it. Most of our industrial processes are not automatic at all, and I would like to make a plea to all the manufacturers to drop that word. It is too much of a misnomer. We try merely to sell machines doing part of the operation of the man, machines to be used as a refined tool by operators.

Mr. Leahy also made the remark that there is almost no control of open hearth furnaces; he forgets that there always is a first helper ,who acts as regulator. You use the first helper as the controller; you use the human machine as the controller.

With regard to the transformation of the O. H. process. It costs about $3 to $4 to transform cast iron into steel. I say that is a rough figure. I don't want to be quoted on this, nor nailed down. Of that $3, about one-third is fuel cost, about one-third is labor cost, and about one-third is material cost (maintenance). Those figures can be found in the literature. The whole margin, we have to work on, is rather small. I know some plants where the transformation cost is less than $2, and I know other plants where the transformation cost is over $4. Some plants have fuel costs as small as 95 cents. Other plants have the fuel transformation as high as $1.80. Those are the dollar figures which the manufacturer has to meet in the competition with the man operation in order to give to his machines an investment value.

There is no point in giving too definite figures in this matter because you will ask me where I got them, and I don't want to disclose the source of my information. I feel that that problem has always to be kept in mind by the designer and the man who installs those machines. The investment value of the regulator has to come within the economic limits of the problem.

**A. W. Steed:** I would like to ask one question. Are the returns greater in using control apparatus, that is, what we have on the market? Is there any differential between a rich gas and a lean gas? For instance, with a producer gas where your carbonhydro ratio is 11 to 7, and the fuel oil 7 to 1, is the return any greater on the lean gas than it is on the richer gas?

**F. E. Leahy:** This question is quite general and can only be answered in a general way. The most that can be claimed for combustion control is a means of maintaining the correct proportion of air to fuel. Also a means of controlling the draft. In a given furnace if the lack of such control was the cause of irregular results then the control will bring an improvement. Combustion control can hardly correct for poor design of furnace or unsatisfactory producer operation. Failure to appreciate this has in some cases resulted in the combustion control being condemned unjustly.

**A. W. Steed:** I was thinking primarily of control apparatus, where you are controlling the operation of the furnace.

**F. E. Leahy:** Another thing of interest to me was in talking to a representative of a certain plant in the West, who has an open hearth furnace under full machine control, he said the quality of the steel itself was improved mainly through the avoiding of oxidation of his bath, or at least the amount of oxygen or oxide absorbed by the bath itself was noticeably reduced. He could make a better grade of steel. Those familiar with the making of steel know there is a certain period in making a heat the bath is exposed to the gases and has slag protection. At that period, the bath is rather critical, and if subjected to very much excess air at the temperature the air comes from the checkers, a rapid absorption may take place which may cause an excess absorption of oxygen. By having a furnace controlled to prevent this condition the operation is improved to that extent.

We have been experimenting with a control equipment on an open hearth furnace and the operator can do promptly what he would otherwise have to accomplish with a loss of time. Most of the valves, for instance, on an open hearth, are too cumbersome and were apparently never intended for anything but occasional setting. It takes a heavy wrench and a lot of struggling on most furnaces to move the valves. You can't expect a first helper to struggle

with those valves very much more than once a turn, and sometimes not even that much. With control equipment, if he wants more air he can turn a small knob and get it. I think it will take time for the men themselves to become thoroughly familiar with the possibilities of such equipment.

It is quite interesting to note how a start in the use of control leads to the extension in the use of additional equipment.

Depending on local conditions and opinions the start may be made using part of a complete control system.

Where the control is found reliable and will maintain the settings consistently the desire for the complete equipment soon develops.

In most cases the success of such equipment is a matter of close co-operation between all parties sharing responsiblity in the successful operation of a furnace and the closer their efforts are co-ordinated the more satisfactory will be the final results.

# *Recent Developments in Industrial Furnace Design**

By G. R. McDERMOTT

## DISCUSSION

**Discussed by**

*G. R. McDermott, Vice President, Chapman Stein Co., Mt. Vernon, Ohio.*
*F. E. Leahy, Combustion Engineer, Youngstown Sheet & Tube Co., Youngstown, Ohio.*
*W. P. Chandler, Chief Engineer, Furnace Equipment Department, Blaw-Knox Co., Blawnox, Pa.*
*A. L. Culbertson, Manager Furnace Division, Rust Engineering Co., Pittsburgh, Pa.*
*H. Dobrin, Consulting Combustion Engineer, Pittsburgh, Pa.*
*E. A. Brown, Jr., Assistant Chief Mechanical Engineer, Carnegie Steel Co., Munhall, Pa.*

**F. E. Leahy:** I'd like to compliment the author first on the very excellent paper he has presented today. He brought out some very interesting features in the development of the heating furnace.

For years there was a wide gulf between the design of so-called "heat treating furnaces" and the "heating furnaces." The heat treating furnaces were designed from very accurate and scientific principles and performed excellently. In many cases, steel heating furnaces were very elementary in design, cheap to build and satisfactory if able to heat steel sufficiently to get it through the mill.

Probably more attention to cost has resulted in a demand for greater accuracy and greater improvement today. I believe we find it profitable to build the best furnaces that are capable of heating the quantity, at the quality necessary for the mill.

Another feature that has contributed quite a little to the advance of heating furnaces is the interest of the metallurgists in the results from good heating. Today we find the metallurgists co-operating very closely with data on heating effects and in some cases specifications that give a very close outline for the design of the furnace.

I think that the field Mr. McDermott covered today is very broad in the general use of furnaces in the steel mills of today.

Again I'd like to compliment him on his excellent paper.

**W. P. Chandler:** The description of the construction and performance of one way fired soaking pits and continuous heating furnaces of the type mentioned in Mr. McDermott's paper is most interesting. We desire, however, to take exception to some of the statements and will consider first the case of continuous furnaces with special reference to the economical operation obtainable with proper burner equipment and the use of preheated air.

The operation of a continuous furnace of the type described at the high heating rates results in high temperatures of the waste gases leaving the hearth. Under the circumstances the low efficiencies mentioned in the paper are not surprising. In order to avoid this poor performance, provision should be made to return to the furnace as much of the heat in the waste gases as possible by preheating the air for combustion to the maximum temperature obtainable.

The paper infers that higher efficiency is not obtained with higher air preheat, but this is obviously incorrect if the higher air preheat is utilized in a proper manner. Mr. McDermott touches the crux of the matter a little further on when he states that the air preheat which can be utilized depends on the type of port employed. It is true that intimate mixing burners and those of the low velocity type are not suitable for utilizing high preheated air in connection with most continuous furnaces. However, if the preheated air is delivered to the burner under a slight pressure, sufficient velocity can be given to the gas air stream, and the degree of mixing can be regulated so as to produce the desired flame condition in the furnace. This fact is born out by the author's statement that the use of a certain percentage of cold fan blown air in order to give velocity to the low pressure preheated air, will produce proper flame control. The use of cold air however means a reduced efficiency and with the keen competition of the present day and the consequent demand for low costs it is essential that furnaces be equipped to handle combustion air at as high a temperature as possible.

The proper distribution of temperature within the

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furnace requires proper flame control and can only be accomplished if sufficient velocity is present in the gas air stream leaving the nose of the burner. Producer gas is delivered to the furnace at too low a pressure to impart the required velocity to the stream of gas air mixture. The author advocates using some fan blown air to give the required velocity to the total air so as to obtain proper flame control. A similar need for air velocity exists in the case of coke oven or natural gas as the author points out. These gases require approximately fifteen times their own weight of air for complete combustion so that as mentioned in the paper the kinetic energy resulting from the velocity of the gas stream alone is not sufficient properly to control the flame in the furnace. It is evident that no matter what fuel is used the air as well as the gas must impart an appreciable velocity to the combustible mixture. This is most simply and economically done by delivering all the air for combustion to the burners properly preheated and under the necessary pressure.

The use of a pressure burner as distinct from an aspirating burner is also advantageous due to the variations in firing rate met within practice. The range of an aspirating burner operating with the low pressure described is very limited and the percentages of cold air delivered to the furnace would undoubtedly increase materially at the lower rates of firing. The use of aspirating burners employing cold pressure air, low pressure hot air and fuel gas is an unnecessary make shift to overcome the difficulty of not having preheated air at the requisite pressure.

While the maintenance of the desired temperature distribution within the furnace is properly a function of the burners, the design of the furnace modifies the requirements. In some furnace designs the roof is sufficiently high to allow placing the burners in such a position that the flame can radiate part of its heat to the steel in the cooler part of the furnace. Mr. McDermott points out that in one type of furnace of such design the tendency towards high flame temperature incident to maximum air preheat will not cause difficulties due to overheating the steel at the discharge point.

The operation of one way fired soaking pits requires control of the velocity in the flame to even a greater degree than for continuous heating furnaces due to the form of the gas travel in the pit. Much that we have said regarding burners for continuous furnaces applies also to soaking pits of this type.

The use of a metallic regenerator for preheating the air for combustion allows the delivery of air at the burners under the necessary pressure required for proper flame control. As mentioned by the author any piece of apparatus which may be subjected to destructive temperatures must be safe guarded. It is due to this fact that automatic means are provided in connection with the metallic regenerator for maintaining the inlet waste gas temperature below the point liable to cause damage. This is accomplished by recirculating the necessary part of the cooled waste gases through the heater when the inlet temperature tends to rise above the safe limit. The author mentions the bleeding of cold air into the waste gas flue as being requisite. This condition is neither requisite nor desirable for regular operation. When starting new installations with the operators unfamiliar with the equipment, cold air has been admitted to the waste gas flue in certain instances in order to insure against improper operation of the pit damaging the regenerator. With the equipment as now furnished this is no longer necessary or desirable. A number of pits have been in successful operation for over a year with no air admitted to the waste gas flue. The fusible link referred to by the author is comparable to the fusible plug in a boiler, and its presence like the plug in a boiler is only an added safe guard.

The remainder of the controls which the author lists as necessary evils of a metallic regenerator are simply combustion controls which are being installed in connection with a great many furnaces at the present time and which are just as desirable for the recuperative soaking pits mentioned in the paper unless the author knows of a supply of operators not subject to the frailties of the ordinary human being. For general information we would state that a soaking pit equipped with a metallic regenerator but not equipped with any of the automatic combustions controls, has operated over a long period and demonstrated that successful operation is not dependent on a multitude of regulators and automatic controls.

In closing, we would like to repeat the last paragraph of the speakers article on economical combustion published along with Mr. McDermott's paper:

Operators and engineers should give careful consideration to the maintenance of maximum economy in furnace operation through the use of maximum air preheat and should provide means for controlling the temperature conditions within the furnace through proper burner equipment.

**A. L. Culbertson:** We wish to compliment Mr. McDermott on his paper which shows beyond doubt that there is a general trend toward improved furnace operation with regard to tonnage output, quality of heating and fuel efficiency, both on the part of the steel plant operative and the furnace manufacturers.

In reading through Mr. McDermott's paper, we could not help but give thought to the actual heating conditions which occur in any soaking pit and compare them with the conditions met within continuous furnaces. We feel that it would be instructive for us to point out this analogy at this time, and have it appear in the discussion of this paper.

Soaking pits have been used in the steel industry ever since the time steel was first made and cast into ingot form. At first, they were used, as their name implies, to perform the operation of "soaking" only. The hot ingot was stripped while it still contained molten metal and sufficient heat therein to equalize the ingot throughout at a satisfactory rolling temperature. In the original soaking pits, no additional fuel was applied and a true "soak" of the metal was obtained due to the heat contained in the center of the ingot distributing itself throughout the mass, warming up the chilled section and finally being entirely equalized, at which time it was rolled. This original type of pit was so constructed that only a small amount of heat was lost by radiation through the walls, and the time allowed for the ingots to equalize themselves to a rolling temperature was termed the "soaking period."

Over the years, production of ingots per heat increased. The time required between pouring and charging the ingots into the pits increased and too

much heat was lost to continue this old method of soaking. Fuel was then supplied to the pit furnace in order to make up for that which was lost before charging. Many times it was necessary to heat cold ingots. The form of the soaking pit gradually changed until it was made a heating furnace as well as a soaking pit. Regenerators were added in an effort to save fuel and increase speed of heating. Then came the recuperative soaking pit as constructed by the Chapman-Stein Company with tile recuperator, and more recently the one-way type of pit with regenerative Blaw-Knox preheater which provides a more positive pressure air supply at any predetermined temperature up to 1400° Fahrenheit was developed and first constructed by The Rust Engineering Company. Each step showed an advance, from a fuel economy, greater production or a space saving standpoint. Still, the heating operation is exactly that required in the original soaking pit; viz., a soaking period is essential in order that the temperature of the entire mass may be permitted to equalize throughout before it is satisfactory for rolling.

The old original soaking pit contained no heating operation, and its entire cycle was one of soaking. Modern pits first have a period of heating and end up as originally, with a period for soaking.

When considering cold ingots being charged in the soaking pit, it is desirable to apply a maximum flame temperature in order to obtain rapid heating and, accordingly, higher production. It is, therefore, possible to use as highly preheated air as can be obtained and, accordingly, the highest flame temperature available during the first portion of the heating cycle on any soaking pit. As the ingots become heated, it is found that they do not heat exactly uniformly throughout their length. Sometimes a pit heats the bottoms faster than the tops. Others heat the center portion of the ingots first. In still others ,the tops of the ingots are heated primarily.

The soaking pit heater, as he watches the ingots approaching a dangerous temperature, may do one of several things . He may shut his pit entirely off and permit a preliminary soaking to equalize the ingots somewhat; he may reduce his firing rate greatly, or he may reduce the flame temperature of his combustible mixture so that no damage is done to the ingots being treated.

The old practice commonly followed on the brick regenerative type soaking pits called for the heater to flood the pit with excess gas to protect the steel. This additional gas merely acts as a tempering medium to the flame and reduces the flame temperature to a point where it does not injure the steel. Such a practice is wasteful of fuel; yet it is essential unless other means are provided to obtain the same results. In finishing a charge of ingots, it is desirable for uniformity of heating conditions that the flame temperature be but slightly above that of the ingots contained in the pit so that the conditions be as nearly as possible the same as those which existed in the original soaking pit where no heat was applied at all. The fuel supplied during this finishing period is generally only that necessary to take care of radiation losses and convection losses, and is accordingly the lowest firing rate of the entire cycle.

An analysis of this soaking pit heating condition showed its analogy to that desired in proper continuous furnace operation, and was the basic thought which resulted in the actual design and construction of the first Zone Controlled Triple Fired Furnace. This furnace is in effect a tandem furnace, having first a heating chamber in which the preliminary heating operation takes place and, second, a soaking chamber in which the quality of heating desired in the discharged product is obtained exactly in the same manner as that carried out in soaking pits. When cold steel is pushed in at the charging end of the Zone Controlled Furnace, it is heated rapidly while it passes through the heating chamber. The heating chamber is separately fired from the soaking chamber. Since it is taking care of only the heating operation comparable to the first portion of the soaking pit heating cycle, it is possible to use air preheated considerably in excess of the temperatures mentioned in the paper under discussion, where the author stated he was limited to the use of air having a temperature from 500 to 1000° Fahrenheit. It is not desirable to limit the amount of preheat in the air, inasmuch as with the Zone Controlled type of furnace the air preheater is considered only as a heat salvaging device to be operated at its maximum efficiency, since highly preheated air means more fuel saved. Temperatures of 2800° Fahrenheit are used in the heating chamber when the furnace is being forced to high output, with no deleterious effect upon the steel or refractories. The steel is heated by adjusting the firing rate to that suitable for the tonnage desired so that it passes into the soaking chamber before it has reached a washing temperature. The soaking chamber is exactly that which the name implies. It is a separately fired chamber in which the temperatures maintained are but slightly above that desired in the discharged product. Only sufficient fuel to take care of radiation losses is supplied to this chamber and no attempt is made to heat the steel, which already contains sufficient heat for rolling when it enters the soaking chamber, although not entirely equalized throughout. Equalizing occurs while the steel passes over the well insulated chrome faced refractory hearth of the soaking chamber and the finishing operation on the steel passing through the soaking chamber is once more identical to the finishing operation in the heating cycle of the soaking pit.

These conditions are accomplished in the Zone Controlled furnace without constant burner adjustment by the operator, which is an essential part of the soaking pit heater's work. It is necessary for the soaking pit operator to obtain in a single chamber all of the heating conditions, flame temperatures and the proper protective atmosphere by manipulating his valves and dampers throughout the entire heating cycle. The same conditions are obtained in the Zone Controlled furnace continuously, for the conditions of the various portions of the furnace are held constant during any definite tonnage rate of output. At all rates of output, the soaking chamber is held with a constant temperature and atmosphere. The heating chamber firing rate varies in accordance with the tonnage demand of the mill.

The Zone Controlled design of furnace makes it possible to utilize as highly preheated air as is possible to obtain. All types of preheaters can be used

on this furnace. When using a Rust Refractory Tile recuperator, it is possible to obtain a higher pressure in the high temperature air delivered to the top tier of burners than would be the case if the air were cooler, since the pressure is determined by its average temperature and the vertical distance it travels in passing from the air inlet of the tile recuperator up to the firing ports.

It has been found in the actual operation of several such furnaces that this type furnace requires only three to four ounces of gas pressure, although using venturi burner block mixing ports to provide a proper mix of the air and gas before entering the heating chamber. Yet sufficient air for any combustion rate or atmosphere is always available. No cold air jets are required to help supply the combustion air, nor are they essential in obtaining the proper mix. This has not only been found with regard to the use of coke oven gas on continuous furnaces equipped with tile recuperators, but has also been found true on furnaces fired with natural gas which, per cubic foot, requires twice the volume of air as is needed for coke oven gas. The temperature of a flame is varied by the degree of preheat used in the air for combustion. A Zone Controlled furnace can use highly preheated air since the high flame temperatures are developed in the heating chamber and not at the point of discharge. An end fired furnace must, of necessity, use some means to lower the flame temperature and provide a soaking condition. Cold air or a mixture of cold and hot air will accomplish this result but at a lowered average furnace temperature and, consequently, a lowered furnace efficiency.

Heating by radiation, as pointed out in the paper under discussion, is extremely rapid, being proportional to the difference of the fourth powers of the temperatures of the material being heated and the flame. Heating by radiation is extremely rapid in the heating chamber of the Zone Controlled Furnaces since the large heating chamber is filled with a flame which has the maximum temperature obtainable, and is, no doubt, several hundred degrees higher than that which would be permissible if fired where the steel is about to be discharged for rolling, as is the case with the end fired furnaces described here today. The discharging end of any continuous furnace should be carried at a temperature but slightly above that of the steel. This is the case likewise in soaking pits at the finish of their heating cycle.

The depth of flame and its increased radiating power described as a benefit in the paper just read is, therefore, negligible at the discharge end of any furnace and these claims cannot be considered of any value whatever for the reason that if radiation is taking place the top of the material is absorbing heat. If the top of the material about to be discharged is absorbing heat, then it will be discharged in an improperly heated condition which is not desirable.

The furnace shown on the third slide is a Double Fired Zone Controlled Continuous Furnace serving a merchant mill in Canada. A mixture of coke oven and blast furnace gas is used on this furnace. The fuel consumption of 1,200,000 B.t.u. per ton has been obtained over a sixteen-hour period. That was the total period available for testing, due to two-turn operation. 1,200,000 B.t.u. per ton is the approximate equivalent of 104 pounds of coal. This furnace has a sloping hearth and heats billets 15 feet in length, varying from 2" to 4" in thickness. An interesting point is with regard to the distance that it is possible to push small section billets. The entire pushing distance is 53 feet with the hearth containing a slope of 2" per foot.

While Zone Controlled Furnaces, either Double or Triple Fired, are designed for a normal heating rate of not more than 110 to 120 pounds per square foot of effective heating surface, conditions have arisen during which the furnaces of both types have been pushed far beyond capacity and heating rates have been obtained approximating 140 pounds per square foot. Fuel consumptions have been obtained on furnaces of this design equipped with water-cooled skids and heating thick blooms and billets of only medium length, showing a monthly overall fuel figure of approximately 130 pounds of coal per ton. Daily overall fuel figures show as low as 112 pounds of coal per ton, with the same type furnace. Test figures have shown less than 100 pounds of coal per ton on the Zone Controlled Furnaces equipped with sloping hearth and no watercooled skids.

**H. Dobrin:** All that has been brought out by Mr. McDermott in his paper and also Mr. Culbertson in his discussion has been very interesting. I might add, however, that along with proper heating equipment has come something which executives in the steel industry did not expect would come, namely, the amount of steel that can be saved in scale by the introduction of quality heating over the old hit and miss type of heating.

In a case that I happen to particularly know about, the scientific application of heat for ingots has reduced the scale loss to less than 1%. Their own best experience previous to that had been that they lost about 2½% in scale. This question is one which is very hard to definitely determine. The blooming mill superintendents like to fool themselves about the scale loss experienced in ingot heating. Some of them will go so far as to admit 2½%, but if you take the difference between the finished blooms and the crop ends and compare it with the charged weight, there is more than 5% missing. This fact is hard to put across with the superintendents in blooming mills.

In one case where it was desired to definitely establish this loss it was done as follows: An ingot was heated in a pit which we will, for the sake of argument, call the non-controlled pit, representing the old style pit. This ingot was weighed before charging, and after the first four passes in the blooming mill it was weighed again. This ingot showed a loss in scale of 2½%. Another ingot was charged into a pit which, for the sake of identification, we will call a controlled pit. This was also weighed before charging and weighed again after the first four passes in the bloomer. This showed a loss of only .77%. It has been found that in the controlled pit it is possible to heat an ingot without any scale. Since the atmosphere is strictly under the control of the operator, it has been found desirable to produce some scale on the ingot towards the end of the heating cycle. The latter is for the purpose of removing some of the surface imperfections that usually form on an ingot. Most ingots will

have some of these imperfections unless you shake them down in the mold while pouring.

Now, in the papers and discussions we have all talked about pounds of fuel, but if you can save 1% of steel, this amounts to more money than the usual cost of heating the ingots. If you can save 1% of steel out of 100 tons, you will have one ton. Assuming that a ton of steel is worth $25, you have therefore saved 25 cents per ton on each 100 tons of steel that you have heated in the soaking pit. Now we all know that it takes a good deal of fuel saving to save 25 cents per ton, so the whole subject having to do with heating furnaces and soaking pits opens up possibilities which were not thought of in recent years.

I had occasion to discuss this question with some of the boys last night coming up on the train, and we all agreed that fuel economy is fine, but it does not amount to anything without quality. It also invariably happens that as soon as quality heating is achieved, fuel economy usually follows as a natural result. The proof is that people have never gone back to the old and ancient applications. Once people in the industry have found the value of quality application of heat, the history has been that they have further extended the introduction of quality heat application. The people who have tasted the benefits of quality heating have been encouraged to go on and on, and it is only the people who have no modern applications that it is very hard to convince of the benefits that may come to them from modern heat application.

The furnace interests have been very energetic in bringing to the user of fuel in the steel business ideas and improvements. But the work that has and is being done by the fuel engineers in the different plants is of great importance. These men are the apostles, the missionaries, the educators. They put forces at work in the mill which the furnace builder, the one commercially interested in the sale of furnace equipment, is unable to do. The fuel engineer is the vital force in the steel works. He conducts the work of education and prepares the ground for the furnace manufacturer. But more important still, after the furnace organization has built a job, it is up to the engineer in the plant to make it a success. The fuel engineer must follow up this work and educate the men in the organization as to how to get the best out of the furnace unit. You will find that usually, whenever you have a well conducted combustion engineering department in a plant, the road is so much easier for the people who have furnaces to sell. On the other hand, you can put in the finest furnace unit in a mill, and if the organization is not educated up to it, you cannot get the results. This is the reason why so many well planned jobs, put in at great expense, often fail in the mill.

The discussion that has been brought out certainly was very interesting, that is, to the furnace people and also to the fuel engineering fraternity. I know from personal experience that the steel mill executives are beginning to realize more and more that it pays to spend money on furnace equipment.

**E. A. Brown, Jr.:** I have not much to add, but would like to raise a couple of questions. I was surprised that Mr. McDermott and Mr. Chandler differed so widely in regard to the amount of preheat desired, and would like to hear from both gentlemen regarding the stack temperatures which they anticipate with these higher or lower preheats. Since the stack temperature is quite a measuring stick regarding efficiency in this case, this discussion would be valuable.

Another point—Mr. McDermott has had a very large subject to cover, and I appreciate that he had to limit his paper. I was sorry, however, that he did not mention the "in and out" type of furnace at all. I think it is probably the consensus of opinion that where the continuous furnace can be applied that is the only practical thing to do. However, some of the plants, like the one with which I am associated, possibly cannot apply continuous furnaces to their product. I refer especially to the heating of plate slabs at plants where the wide variation in size of slabs leads to difficulties with the continuous furnace. It is no doubt true that such industries will probably have to live with the "in and out" furnace for some time yet, and I am interested in the latest developments along that line. I have appreciated the papers and discussions throughout.

**G. R. McDermott:** I want to express my thanks for the discussion which the paper has brought forth. I certainly appreciate it,—for only through constructive discussion are we able to learn more of the particular subject.

Regarding the question of the degree of air preheat brought out by Mr. Chandler's discussion. We, of course, desire to use as high combustion air temperature as possible from a fuel economic standpoint; however, we have found that, although available, there are certain practical limitations regardless of the furnace port design. As an example, we have found in heating wide slabs for continuous Strip Mills, especially when using hot producer gas that, although having the combustion air available at a temperature of 1000° to 1200° F., it produced undesirable steel heating results. This condition is corrected when using a temperature between 800° to 900° F. The modification of furnace port designs, such as to delay mixing of the fuel and air will, of course, produce statification of the furnace atmosphere, which is not conducive to quality heating.

Mr. Brown has requested an expression as to the relative merits of the conventional sand bottom, or in-and-out, furnace as compared with the continuous furnace for the heating of slabs for Plate Mills. We have never built the typical in-and-out furnace,—not having had any particular demand for them; however, we have built a great number of continuous slab heating furnaces for continuous wide Strip Mills now in operation. The results obtained by this particular type of mill from a standpoint of the finished gauge required has demonstrated that a correctly designed continuous slab heating furnace will give the desired results from a standpoint of uniform and thoroughly heated steel with a minimum amount of proper slab surface scale. The fact that one of the prominent steel companies has decided to install continuous slab heating furnaces for a continuous Plate Mill, I consider as indicating the trend. This particular company has in-and-out furnaces in operation with their existing Plate Mills. The economies effected by the use of the continuous furnace when installed in connection with the wide

continuous Strip Mills might just as well be obtained with the Plate Mills. We all know that the conventional in-and-out furnace is inefficient as compared with the continuous furnace from a standpoint of fuel consumption and maintenance. There is one condition which will require investigation, and that is, in order to meet the varying orders on the mill, whether it would be possible to heat uniformly and push the varying slab weights and sizes through the continuous furnace. It would be necessary in this case to have some idea of the slab dimensions usually rolled on the particular mill in order to definitely state whether they could be pushed through the furnace. I hope that this answers Mr. Brown's question.

I want to thank you again for your kind attention.

# *Automatic Pressure Lubricating Systems for Roll Necks*

By MAURICE RESWICK*

### Historical Sketch

The science and practice of lubrication in the steel industry has been advanced very materially during the past decade. Improvements in bearing design and lubrication practice, however, were largely confined to reduction gears, pinion stands, roll tables and other auxiliary equipment, while the rolling mill stands proper were left out of consideration for a long time, the feeling being that the roll necks were being lubricated about as well as they could be under the circumstances.

Various attempts were made in the past to devise automatic and semi-automatic lubricating systems for roll neck bearings, but these did not prove successful largely because the mill operators were not ready for them so long as tonnage output was the only thing that mattered and operating costs were of secondary consideration. The situation is now changed, and mill operators are compelled to reduce operating costs to a minimum wherever possible.

In the past three years a number of ingenious devices were developed for automatically feeding grease under pressure to the main roll neck bearings. Nearly all of these lubricating systems had their birth in the steel plants, first in a crude form, then gradually developed and refined until today they are proving their value and their practicability wherever used. The life of bearings has been increased, power consumption reduced, waste of lubricant prevented, maintenance costs and mill shut-down decreased, and safer operating conditions realized.

There is yet much to be accomplished, but through the combined efforts of grease manufacturers, machine designers and builders, lubricating devices manufacturers, and mill operators rapid progress is being made toward the satisfactory solution of the difficult problem of roll neck lubrication.

### Types of Lubricating Systems

At present there are on the market several lubricating systems of various designs to meet the particular requirements of any steel mill application. The underlying principle is to deliver grease under pressure to each bearing from a centralized point automatically and in a measured quantity at definite intervals of time. The systems are operated and controlled electrically, mechanically, pneumatically, or by a combination of these mediums, and arranged so that lubrication takes place only while the machinery is in operation.

Some systems make use of the familiar mechanism of the reciprocating pump, in which mechanical or pneumatic pressure is applied at the piston end of a plunger and transmitted to the grease at the other end, causing it to flow to the bearing. The several feed lines in the system may be provided with independent pumping units arranged to operate simultaneously, or a single pump may be used to feed each line consecutively through a properly synchronized distributor head.

Another method of metering grease in several systems is by means of a free-floating piston or plunger inside of a cylinder, constituting a lubricating valve. In one type the grease is maintained at constant pressure in a hydraulic cylinder connected to a grease manifold from which feed lines lead to the bearings, through lubricating valves of the displacement type. An electric or compressed air timing control operates the valves, causing a measured quantity of grease to be delivered to the bearings. In another type the grease is pumped at regular intervals to the lubricating valves until they are filled with grease, whereupon the pressure on the grease line is released and the valves are caused to discharge by pumping oil into the valves on the opposite side of the floating piston.

While it must be admitted that some of the lubricating systems on the market are still more or less in the experimental stage, it is a fact that regardless of the system chosen, an installation of this type generally pays for itself in a short time in resulting economies and improved operating conditions. Any contemplated installation of a lubricating system should be regarded to some extent as an experiment, as minor modifications and adjustments have to be made generally in the system itself or in the bearing connections before it will operate at its best.

### Lubricants Used

With the advent of mechanically operated automatic pressure systems, the grease manufacturers were called upon to develop special lubricants that would stand up under high pressure without decomposing or separating out. The greases furnished

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for this class of work are made up of a high viscosity mineral oil and contain the necessary ingredients to form an effective grease film under pressure and also to adhere to the rubbing surfaces. A lubricating system is no better than the kind of grease used, and the grease manufacturer should be consulted on this subject. Several kinds of greases are usually tried out until the proper grade is determined.

Perhaps the outstanding advantage of any pressure lubricating system is the fact that lighter greases containing a higher percentage of mineral oil—the true lubricant—can be used. Hard greases, packed on the roll necks by hand, depend on the temperature of the necks to give up their lubricating properties, while in a pressure system a softer grease is delivered near the point of maximum bearing pressure, instantly forming a grease film which prevents metal-to-metal contact and preventing the generation of frictional heat. The grease film is maintained because the supply of lubricant to the bearings is regular and in a definite quantity.

**Consumption of Grease**

The question whether the installation of an automatic pressure system will result in greater or lesser consumption of grease cannot be answered satisfactorily. Some plants report that less grease is being used, while other plants report that slightly more grease is being consumed. It is quite obvious that with an automatic system, feeding the grease to the bearings under pressure and in a measured quantity, the most economical point is eventually reached that will assure effective lubrication as indicated by bearing temperature and the life of the bearings. Every ounce of grease is caused to pass between the sliding surfaces of the neck and bearings and none of it is washed away before it performs its purpose.

Where bearings were under-lubricated formerly, due to failure of packing the bearings properly because of inaccessibility while the mill is in operation, a pressure system will result in a slightly greater consumption of grease for efficient lubrication. On the other hand, where most of the grease is being washed away by the stream of cooling water into the scale pit, an automatic pressure system should result in reduced consumption of grease.

In general, the benefits resulting from increased over-all maintenance and operating efficiency, together with reduced power consumption and improvement of operating conditions on the mills, are far more important than the relative cost of lubricant used.

**Design of Bearings**

Where a new mill is being designed and which is provided to be lubricated with an automatic pressure system, it is desirable to design the bearings with special grooves and grease inlets and with sufficient body to accommodate the required pipe connections. The coupling boxes at the side of the mill nearest the pinion stand should be located away from the bearings, sufficient to provide clearance for the pipe connections.

On existing installations old bearings may be readily changed over in such a manner that the lubricant may be forced in through drilled holes in the body of the bearings or through special bronze inserts anchored in babbitt metal. Most of the automatic lubricating systems in present use have been adapted to old bearings originally designed for hand lubrication.

With a pressure system it is possible to control the distribution of the lubricant over the bearing surface, either by admitting the grease where the maximum wear takes place or, preferably, by providing more than one grease inlet. On certain types of rolling mills the greatest wear occurs at or near the thrust collars, and it is advisable in such cases to run a separate feed line to this point. By providing proper lubrication for the surfaces which take the greatest load and which wear out more quickly than the other bearing surfaces, the installation results in an economy and an increase in the life of the bearings which is not possible to obtain with the usual method whereby the thrust collar gets lubrication only from what is carried over from the groove in the radial surface.

The familiar type of "brass" for roll neck bearings is bound to undergo considerable modification in the near future, and the ultimate design will depend largely on the latest improved methods of lubrication. One notable departure has already been made with the introduction of the anti-friction (ball or roller type) bearing for rolling mill service, while the babbitt lined bearing, re-inforced with brass inserts when necessary, is assured to retain its popularity when it is properly lubricated. The ultimate aim is to produce an economical bearing with a large factor of safety and of long life, with the coefficient of friction reduced through correct lubrication to the point where little if any cooling water may be required.

**Life of Bearings**

Reports from a number of steel plants using automatic pressure lubrication are to the effect that the life of bearings was increased from two to twenty-five times due to more efficient lubrication practice. One plant shows a saving of about $90,000.00 a year in reduced maintenance costs. At this plant many bronze bearings have been replaced with babbitt-lined bearings. An appreciable saving in power is shown by the fact that no cooling water is used on certain bearings which could not be operated formerly without a steady stream of water running on them. Improvement in product is also claimed on account of being able to keep the mills in line better when rolling round or shaped sections.

Bearings in steel mill machinery are subjected not only to severe service as regards sudden loads, high pressures and shocks, but also to abrasion by mill dirt. When an automatic lubricating system is used, by forcing a slight excess of grease into the bearings, all dirt, gritty matter, water, scale, acid, etc., is forced out, thus forming an effective seal and lengthening the life of the bearings. This is particularly true where ball or roller bearings of large size are used, the grease being utilized primarily as a seal against water and dirt which are highly injurious to the polished surfaces of the balls or rollers and races.

**Reduction of Labor**

It is to be expected that an automatic lubricating system would result in reducing maintenance labor,

both in millwright and oilwright crews. At one plant the equipment of an entire department with automatic lubricating systems has resulted in reducing the millwright crew by one-half, and one oiler is taking care of the work formerly done by two oilers, with considerably less effort. Periodic shut-downs of the mills for hand lubrication was also largely eliminated, and this is quite an important item where the cost of an idle mill is figured between $200.00 and $1,000.00 an hour.

**Safety**

The hazard involved in lubricating a mill with a hand grease gun or an oil can, where the oiler has to climb over greasy machinery to reach parts not readily accessible, are well known, and an appreciable proportion of accidents in the steel industry is chargeable to this cause. In a centralized system operated automatically and located in an out-of-the-way place, this hazard is greatly minimized, if not altogether eliminated.

# *A Comparison of Alternating-Current and Direct-Current Motors for Auxiliary Drives*

By GORDON FOX*

In planning for the expansion of the steel industry of the U.S.S.R., the question naturally arose concerning the choice of current for auxiliary motors. Several viewpoints were held. Some of the existing steel plants in the country are now equipped with alternating-current auxiliary motors. In other plants 500 volts direct-current is used. German consultants and manufacturers, reflecting prevailing German practice, recommended the use of alternating-current auxiliary motors while the American consultants recommended 230-volt, direct-current motors for all service of intermittent character where mill type motors are applicable.

As this is a question wherein experience and judgment are of greater importance than any theoretical considerations, the writer addressed a questionnaire to some 20 members of the A.I.S.E.E. soliciting opinions and comment. The response to this questionnaire was gratifying. Not a little interest in the subject was indicated, with some differences in viewpoint. The writer therefore believes that a tabulation of the results is due to those who participated in the questionnaire, and that a recapitulation of some of the factors considered may prove of interest to the membership of the Association, in general, although it contains little that is new.

It is impossible, in tabulating a questionnaire, to reflect exactly the diversified and qualified viewpoints represented. However, Table I serves to indicate, in a general way, the attitude of the American engineer in this matter. The most significant points deserve mention.

No engineer recommended the use of A.C. auxiliary motors exclusively. Those who recommended them at all, suggested their confinement to the less exacting service. Those favoring exclusive use of direct-current drives were, in general, emphatic. Those favoring the consideration of alternating-current for special cases were not.

Several instances were cited wherein alternating-current auxiliary drives had proven unsatisfactory and were replaced by direct-current drives. In no case was an instance of the reverse action cited.

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**TABLE I.**

**Tabulation of Questionnaire**

| Questions | Answers | | |
|---|---|---|---|
| | D.C. | A.C. | Qualified |
| Do you prefer A.C. or D.C. for mill auxiliaries? | 19 | 0 | 5 |
| | Yes | No | Qualified |
| Does the superiority of D.C. justify a higher cost? | 17 | 1 | 3 |
| Would you use A.C. for any new installations? | 6 | 12 | 6* |
| Have you any A.C. mill motors in use? | 2 | 11 | 0 |

NOTE:—Answers in "qualified" column are also listed in previous columns thereby indicating that preference stated is conditional or qualified.

* All "yes" answers were qualified, limiting A.C. motors to less important and less exacting drives.

The exclusive use of A.C. in steel plants would afford these principal advantages, namely:

(1) Elimination of conversion equipment in favor of transformers having lower cost and less space requirement and requiring less operating attention.
(2) The avoidance of conversion losses, only transformation loss being involved.
(3) Elimination of commutators.

These advantages, it will be noted, apply primarily to first cost and operating cost of electrical plant. They apply only indirectly to the prime consideration, steel production.

The principal advantages to be gained through the use of direct-current motors and control for steel plant auxiliaries may be briefly listed as follows:

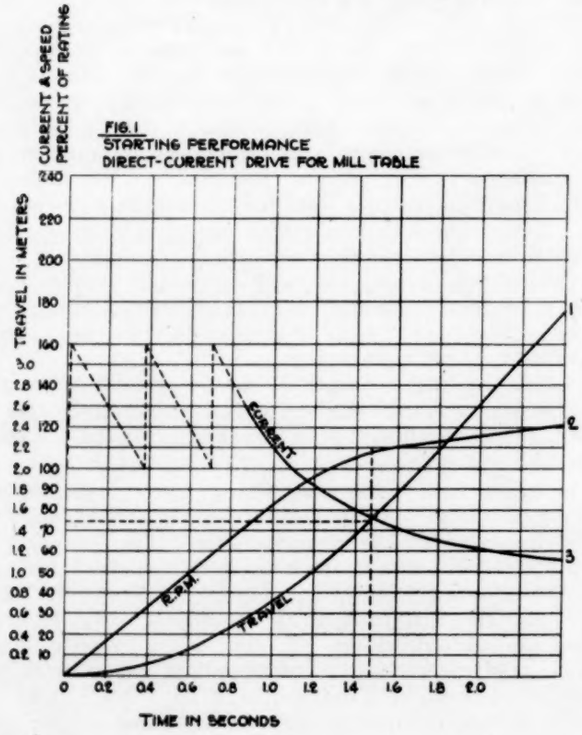
(1) More rapid and responsive action of motors and machines.
(2) Superior torque characteristic.
(3) Superior speed characteristic with inherent adaptation of speed to load.
(4) Superior controllability of speed.
(5) Dynamic braking.
(6) Ability to handle overhauling loads and to slow-down.
(7) Ability to operate two motors in series.

(8) Ability to use series-parallel control.
(9) Lower $Wr^2$ of rotors.
(10) Wider air gap.
(11) Better mechanical construction and easier change of rotors.
(12) Better performance of cranes.
(13) Better and more compact brakes.
(14) Superiority of magnetic control.
  (a) greater simplicity
  (b) greater flexibility
  (c) lighter weight
  (d) faster action
  (e) time-principle acceleration
  (f) less hammering and noise
  (g) more compact
  (h) more highly developed
  (i) cheaper
(15) Greater simplicity of distribution, 2 to 5 cables being required, rather than 3 or 6.
(16) Ability to operate on "ungrounded" system, minimizing delays due to grounds, dirty insulators, etc.
(17) High plant power factor resulting from the use of synchronous motor-generator sets or converters.
(18) Simpler theory. Direct current motors and control are most readily comprehended.
(19) Simplified machinery, due to flexibility of motor control.

Most of the advantages above stated are of such character, that they have a direct bearing upon plant productivity. While space limitations prevent full discussion here of all of these factors, some of them may well be considered more in detail.

One of the arguments favouring the use of A.C. auxiliaries lies in the fact that conversion equipment and conversion losses are avoided. It is often assumed, as a corollary, that alternating current auxiliaries will consume less power than direct current auxiliaries. Let us consider this phase of the question a little more carefully.

Fig. 1 indicates approximately the conditions existing in a typical action of a direct-current auxiliary motor, in driving a mill table, for instance. The control is shown cutting out the accelerating resistance in two steps, in the time of 0.7 seconds. At this instant the motor has attained about 60 per cent of its rated full-load speed or about 50 per cent of its free-running speed. The acceleration continues, with the motor connected to full voltage, until, after 1.47 seconds, the table has travelled the required distance. The current is then shut off. At the instant that the current is shut off, the speed is about



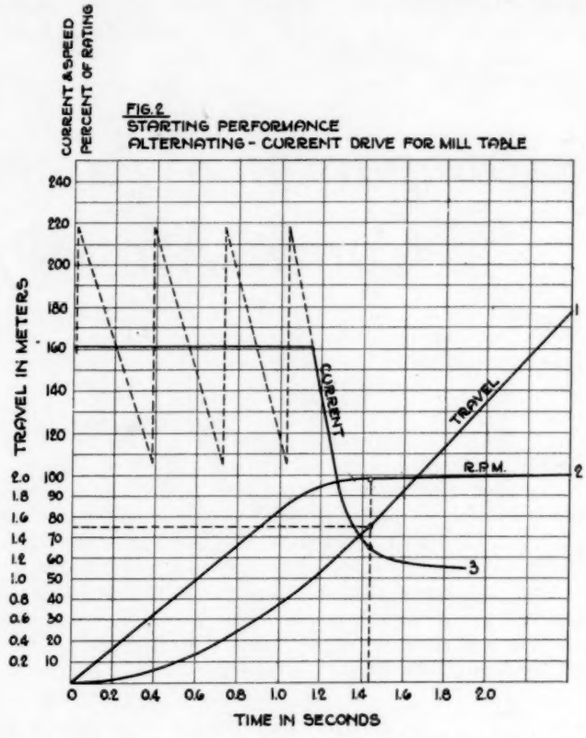
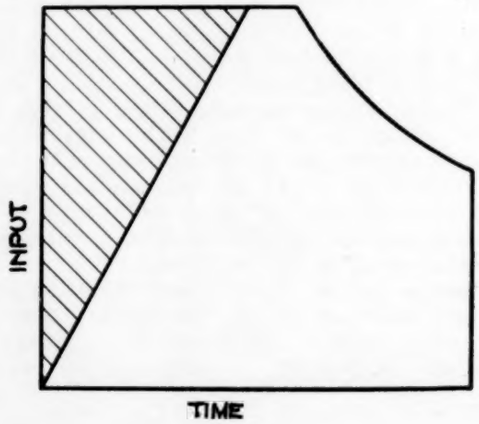




FIG. 3
ENERGY INPUT TO DIRECT CURRENT DRIVE

| | |
|---|---|
| TOTAL ENERGY INPUT CALLED | 100% |
| ENERGY CONSUMED IN RESISTORS | 23% |
| INPUT TO MOTOR | 77% |



108 per cent of rated full load speed and the current has fallen to about 80 per cent of rated full-load current.

In Fig. 3, the energy input for the drive is approximately shown, based on the theory that uniform acceleration is maintained. The shaded area represents the loss in accelerating resistors. When starting from rest, nearly the entire energy input is absorbed in the resistors. This decreases as the motor accelerates and the armature voltage increases. It will be noted that the accelerating resistors consume about one-quarter of the energy input for this cycle, when starting from rest.

Figure 2 is an endeavor to show, in a comparative way, the conditions existing in the typical action of an alternating current induction motor applied to the same service.

In a direct-current series-wound or heavily compounded motor, the torque increases more rapidly than the current, because the field strength increases as well as the armature current. If it were not for saturation of the iron, the torque would increase as the square of the current. If full load current be taken as 100 per cent, the amount of current required to produce 100 per cent and 188 per cent torque (corresponding to arbitrarily selected peak and valley currents during acceleration) are shown in Table II to be 100 per cent and 160 per cent and the average current during acceleration is 130 per cent.

**TABLE II.**

**Comparison of Motor Performance During Acceleration**

Figures represent, approximately, per cent of full load rating. See text

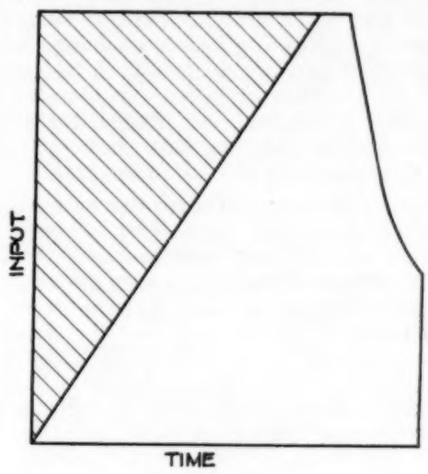
| | D.C. Motor | A.C. Motor |
|---|---|---|
| Minimum valley current | 100 | 105 |
| Minimum valley torque | 100 | 100 |
| Maximum peak current | 160 | 218 |
| Maximum peak torque | 188 | 188 |
| Average accelerating current | 130 | 161 |

In the induction motor the torque-producing ability of the secondary current, decreases as the load increases and the slip increases, (due to the phase relation of this secondary current). If 100 per cent be taken as the theoretical current required to pro duce a full-load torque with the rotor current in phase, the actual secondary current values required to produce the same accelerating torque and the same acceleration rate as selected for the direct current case, are approximately as shown in Table II. By comparison, it will be noted that the direct current motor passes about $\frac{130 \times 100}{161}$ or 80 per cent as much current (relatively) through the accelerating resistors as does the induction motor. The resistor losses are correspondingly effected.

With the direct-current series motor, full voltage may be applied when the motor attains about 60 per cent of rated speed. In other words, the accelerating resistance, need be kept in circuit only until the motor is partially accelerated. With the wound rotor induction motor, acceleration with resistors in circuit must be continued until the motor attains about 90 per cent of rated speed. If this is done with peak and valley currents comparable to those of the direct current motor, one more step of accelerating resistance and one more accelerating contactor will be required. Similarly, a direct current shunt-wound motor requires more accelerating contactors and more resistors than a series motor requires.

FIG. 4
ENERGY INPUT TO ALTERNATING CURRENT DRIVE

TOTAL ENERGY INPUT TO D.C. DRIVE CALLED....100%
TOTAL ENERGY INPUT TO A.C. DRIVE.....148%
ENERGY CONSUMED IN A.C. RESISTORS.....58%
INPUT TO MOTOR.....90%




The features explained above will be seen by comparison of Figures 1 and 2. Figure 4 has been drawn to compare with Fig. 3. The larger shaded area, indicating the greater resistance loss, is here evident. By comparing total areas, representing, in an approximate way, energy input, it will be found that the direct current motor has accomplished the task with an input of approximately two-thirds of that required by the induction motor. If we concede to the alternating current drive an advantage of 12 points in efficiency (assuming monthly overall efficiency of 97 per cent for transformation and 85 per cent for conversion), the direct current drive will accomplish the task with an overall energy consumption of less than 80 per cent of that required by the alternating current drive.

The above comparison is not strictly accurate and the values determined are not to be considered exact. But the comparison should suffice to show quite definitely that, for manipulating service, the direct current drive is at least equal and generally superior to the alternating current drive in the matter of power consumption. It should be noted that the above comparison is based on starting from rest. For a plugging operation the advantage of the direct current drive is accentuated. It was further assumed that the $Wr^2$ of the drive is equal and that motor efficiencies are equal. Actually, the direct current drive would generally hold advantage in these factors, further enhancing its superiority.

When considering the question of relative power consumption, we must bear in mind that deceleration is almost as important a consideration as acceleration. With direct current drives, dynamic braking can be utilized to a considerable extent. This method requires practically no power from the supply system. With alternating current drive, plugging must be used, involving heavy drafts of power.

It is common practice in America to install two motors, rather than a single motor, for many of the principal auxiliary drives. This practice affords several advantages; it permits the distribution of the driving torque close to the load, minimizing the twisting of shafts; it decreases the gear ratio and may thereby lead to mechanical simplification; it minimizes armature inertia, as two small diameter armatures will usually have less inertia than one equivalent large armature; it enables standard motors of moderate size to be used; it permits smaller parts to be handled, facilitating quick exchange of parts; and sometimes it permits operation to be carried on, at a reduced rate while repairs are made on one unit. But aside from these real advantages, there are two very great advantages, namely, the operation of motors in series and the use of series-parallel control.

Let us consider two alternate drives for a blooming mill screw-down; one drive (A) to comprise two direct-current motors connected in parallel; the other drive (B) to comprise the same two motors connected in series. Let us assume that, in drive A, the gear ratio between the motors and the driven shaft is 4 to 1. In case B, in which the motors are in series, they attain only approximately half speed, therefore, to drive the main shaft at the same speed, the gear ratio must be 2 to 1.

The $Wr_A^2$ of drive A, referred to the motor shaft, is equal to the $Wr^2$ of the driven machine at the driven shaft, divided by the square of the gear ratio, plus the inertia of the two motor armatures. Thus:

$$(1)\quad Wr_A^2 = \frac{Wr^2}{16} \text{ plus } 2Wr_m^2$$

In like manner

$$(2)\quad Wr_B^2 = \frac{Wr^2}{4} \text{ plus } 2Wr_m^2$$

Let us introduce here the values for an actual mill, in which $\frac{Wr^2}{4} = 434$ lb. ft$^2$ and $2Wr_m^2 = 1058$ lb. ft$^2$.

Substituting in equations (1) and (2) we have:

$$Wr_A^2 = 109 \text{ plus } 1058 = 1167 \text{ lb. ft}^2$$

$$Wr_B^2 = 434 \text{ plus } 1058 = 1492 \text{ lb. ft}^2$$

Here the inertia of the entire drive, referred to the motor shaft, is higher with the two motors in series and the 2 to 1 gear ratio, as the inertia of the driven machine is more effective. It must be considered, however, that, for drive B, the motors will attain only half speed and the rate of angular acceleration of the motors need be only one half as great to give equal speed of the driven machine. If $T_A$ and $T_B$ be the motor accelerating torques required in cases A and B respectively, if K be a constant and if "a" be the rate of angular acceleration for case A; then:

$$T_A = K \times Wr_A^2 \times a$$

$$= K \times a \times 1167$$

$$T_B = K \times Wr_B^2 \times \frac{a}{2}$$

$$= K \times 1492 \times \frac{a}{2}$$

$$= K \times a \times 746$$

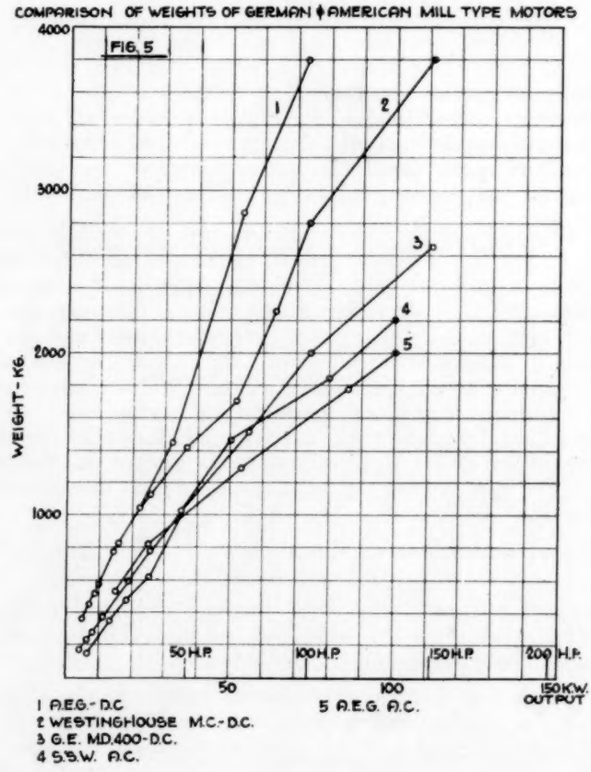
Thus the accelerating torque required for case B, with two motors in series, is about two thirds of the torque required for case A, with two motors in parallel, equal acceleration being obtained in both cases. The accelerating current values are correspondingly less.

It must be further considered that, where two motors are connected in series, the same accelerating current passes through both of them, only one control and one set of resistors are used and the resistor losses are halved.

As a combined result of all the above considerations it will be seen that, for those manipulatory drives where two motors in series may be used to advantage, the direct-current drive will perform a given task, with equal speed, with probably not more than half the energy input required by an induction-motor drive with a single motor or two motors in parallel. In actual practice, the situation is slightly different in that the direct-current drive will be faster than the alternating-current drive and may thereby sacrifice a portion of its advantage in the matter of energy consumption.

The use of two motors in series is particularly advantageous for those drives in which the armature inertia is a principal element of the load. This practice is in common use in American mills for a number of the most important, fastest and busiest auxiliaries such as for the front and rear tables, the screw-down, the side guards and the manipulator fingers of the blooming mill.

It is well known to the American steel mill engineer that due to the more favorable torque char-



acteristic, the higher torque per ampere and the lower inertia of direct-current drives, they are more responsive in action. The influence of this responsiveness upon production is also appreciated. The advantages in speed controllability and those inherent to dynamic braking are also too well known to require comment.

The advantages offered by the direct-current drive in decelerating an overhauling load, are not always appreciated. There are a considerable number of operations in the steel mill wherein it is desirable to travel a considerable distance at high speed, followed by quick deceleration to a slow speed prior to an exact or careful stop. The blast furnace skip-hoist is one such case. Another example is the ingot-buggy which carries the ingots from the soaking pits to the blooming mill. Let us consider the latter.

To respond promptly to the signals of the blooming mill roller, this car, weighing some 30 tons, must travel past a number of pits and must have a running speed of 100 to 150 meters per minute. When this car approaches the end of its travel, it must slow down to a speed of about 15 meters per minute prior to discharging the ingot onto the approach table. Finally it must make an accurate stop. These requirements can be nicely met when using a direct current drive on the car, using an armature-shunting connection to obtain the slow-down, while continuing the driving force in the forward direction, to carry the cycle through to its conclusion. An equivalent performance cannot be obtained from an alternating current drive without undue complication.

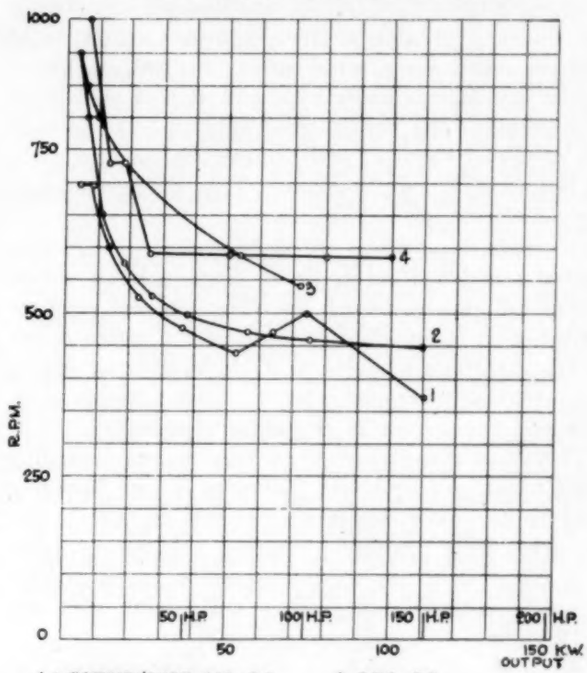
The advantages arising from the practice of operating two motors in series have been previously stated. Quite often it is of advantage to be able to connect the two motors on a single drive either in series or in parallel. With such an arrangement two basic speeds, having a 2 to 1 ratio, are afforded, with no resistor losses at either speed. Other speeds can be derived from either or both of these basic speeds by use of the usual series and shunt resistors. In this manner a wide range of speed regulation can be obtained, with close speed regulation at each step and with minimum loss in resistors. Controllers are available which permit the transition from the series to the parallel connection without interruption of the motor current and torque.

Among the drives which frequently use series-parallel control, may be mentioned: two-motor skip hoists for blast furnaces; bessemer converter vessel tilting; blooming mill screw-down. In the latter case the series connection is used for the frequent short movements in the downward direction while the parallel connection is used for the occasional long movements in lifting the rolls, as when edging a slab.

A comparison of D.C. and A.C. auxiliary motors, particularly as to speeds, weights and inertia moments, is of interest. Fig. 5 is a comparison of weights of both A. C. (50 cycle) and D.C. mill type motors as built by A E G and Siemens Schuckert Company, in Germany and General Electric and Westinghouse in the U. S. A. It will be noted that the German three phase motors are lighter in weight than the American D.C. motors, while the latter are lighter than the German D.C. motors.

Figure 6 is a comparison of rated full-load (American 1 hr. rating, German 40 per cent time rating) speeds of mill type motors. The German motors are designed for higher speeds and, in general, will require somewhat greater speed reductions in the

FIG. 6 COMPARISON OF RATED SPEEDS OF GERMAN & AMERICAN MILL TYPE MOTORS




gearing. The difference is not as great as it appears because, in gearing a D.C. motor having a series characteristic, the free-running speed must be given consideration.

FIG. 7 COMPARISON OF INERTIA MOMENTS OF GERMAN AND AMERICAN MILL TYPE MOTORS

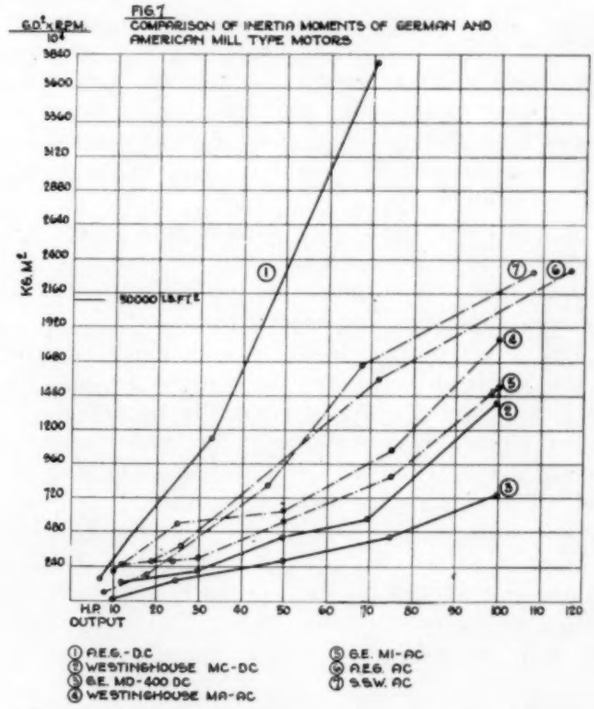



Fig. 7 is a comparison of inertia moments of motor armatures, expressed as $Gd^2$. All figures have

been referred to a speed of 100 R.P.M. so that they may be directly comparative.

The direct current motor is excellently adopted for all the movements required for crane service. Its superiority is particularly pronounced in hoisting duty because of the ability to lower either light loads or heavy loads with proper control, at either slow or fast speeds as desired, and at safe speeds on every point of the controller. This is accomplished with a standard motor, with simple control and without mechanical complications. This performance is of great advantage on all cranes.

Of great importance are the superior speed characteristics and the better speed control of all of the motions of cranes driven by direct current motors. The inherent speed characteristic of the series motor enables the crane to perform its light hook or empty movement at increased speed. This enhances the value and the output of the crane materially.

There are many cranes, such as magnet handling cranes, skull crackers, etc., wherein a fast lowering speed is decidedly advantageous. With direct current drive it is possible to obtain a lowering speed much faster than the hoisting speed, a speed as high as the armatures and gearing will stand, and this fast lowering is under perfect control.

With direct current drive, creeping speeds, both in hoisting and in lowering are readily obtained. This ability is of particular advantage in handling rolls, machinery, etc.

It is highly desirable to use magnetic control for the larger, more important and busier motions of cranes. As magnetic control requires considerable space, its proper location is something of a problem. Alternating current magnetic controllers are 20 to 40 per cent more bulky and are also considerably heavier than corresponding direct current controllers. Crane cages must be very large indeed, to house such controllers.

Magnets are used to a considerable extent for handling raw materials, pig iron, semi-finished and finished steel. A magnet can be easily applied to any crane operating on direct current.

The direct current brake is very much superior to the single-phase alternating current brake. On the direct current operated crane the hoist brake or brakes serve almost exclusively for their important holding duty. They are not called upon to stop the load. The motor does that. Even then, it is essential, for entire safety, that all hoists exceeding 10 or 15 tons capacity be equipped with two holding brakes, one applied to the armature shaft and one applied to the intermediate shaft. This is not difficult with the compact, effective brakes available for direct current.

The holding brakes on the hoist motions of a direct-current crane are connected in series with the hoist motor or motors. The brakes do not release unless and until the hoist motor current is flowing in sufficient degree to carry the load. The use of shunt brakes for crane-hoist duty is unsafe practice. Excellent records for freedom from accidents are only attained through the observance of every possible precaution to protect the workman.

The torque of a direct current motor is not limited by the voltage. If the voltage falls, the motor slows down but continues to produce up to its maximum torque capacity. It is thus inherently and thoroughly safe. The torque produced by an induction motor varies as the square of the voltage. At 80 per cent voltage, only 64 per cent torque is available. The voltage on cranes is particularly likely to be low, due in part to the unavoidable losses in wiring and current collecting devices, including reactance losses.

Magnetic handling crane hoists must be able to develop heavy overload torque for the short period after the magnet is energized and before it breaks away its load from the pile. The alternating current hoist motor, with limited torque capacity, is at a disadvantage in such service.

A direct-current crane motor requires four collector bars. An alternating current motor requires at least six collectors; some proposed arrangements require still more. For the many cranes having five or more motors, this added complication is quite a disadvantage.

Direct-current magnetic control enjoys many advantages over A.C. magnetic control. These are too well known to the engineers of the American steel industry to require comment here beyond their previous mention. One phase of this question deserves some discussion, however.

In the development of D.C. magnetic control in America the "current limit" principle was widely used for several years. This was secured through the use of lockout contactors, series relays, counter-voltage contactors, voltage-drop relays and other variations. None of these systems proved entirely satisfactory. Both users and manufacturers have now accepted the fact that some form of "forced" acceleration is necessary and that the "time" or the "time-current" principles of acceleration are superior for a wide range of uses.

The "time" principle of acceleration has not been so extensively applied for use with A.C. auxiliary drive motors, either in America or elsewhere. No "time" relays comparable to those available for D.C. have been developed. Moreover it can be shown that the usual wound-rotor induction motor is not as well adapted to the use of "forced" acceleration, as the D.C. motor.

When the wound rotor motor operates in a normal manner with the accelerating resistance cut

out by properly adjusted current limit control, the performance is satisfactory. The motor operates with the most advantageous values of secondary resistance as it accelerates, developing good torques with limited and uniform current peaks.

The torque and acceleration curves of a wound rotor induction motor are such that the acceleration can not be unduly forced, that is, the secondary resistance can not be cut below a certain value for a corresponding point on the acceleration curve. If the resistance is cut out too fast, the torque may actually be decreased instead of increased and the motor may refuse to accelerate. Motors with very high pull-out torques can be operated fairly successfully under forced acceleration. The standard commercial motors must have their acceleration regulated in strict accordance with the characteristic curves of the machine, regardless of whether the control is automatic or manual, time limit or current limit.

In America the D.C. auxiliary drive motor and control are cheaper than corresponding A.C. equipment. In Germany the reverse is true. This difference arises largely from the fact that the equipment more nearly standardized and produced in each country in greater quantity is naturally cheaper in that country. It is difficult to evaluate the difference in cost between two steel works, one of which is equipped with D. C. auxiliary drives and the other equipped with A.C. auxiliary drives, for the reason that a comparison of cost of equal motors, control, conversion and transformers does not tell the entire story. There are many modifying considerations. Careful analysis of this matter indicates that the difference between the two systems, if purchased in the cheapest market, would be small.

The total cost of the auxiliary drives in question inclusive of control and conversion equipment represents not to exceed 3 per cent of the total cost of a typical steel works. Thus any saving, which might be made, applies to a very small fraction of the total plant cost. If a saving of 10 per cent were made in the motors and control and if the entire cost of converters (exclusive of transformers) were saved, such saving would be less than one-half of one per cent of the total plant cost. If A.C. motors were installed in the attempt to make this saving, one would be in the position of sacrificing the productivity of over 99 per cent of one's investment in order to make a saving of less than one per cent.

We have indicated, in previous discussion, that the direct-current drive is the more economical in power consumption, even allowing for conversion losses. For the sake of argument, however, let us assume that the alternating-current drive is the more economical. The total power consumption in a typical steel works is on the order of 200 kw. hrs. per ton of ingots. Of this about 1/5, or 40 kwh, is direct-current. Let us assume a 10 per cent saving in favor of the alternating current auxiliary drive. If power costs 1 cent per kw. hr., the saving is 4 cents per ton of ingots. The total conversion cost, above raw materials will ordinarily be approximately $25 per ton of ingots. The power saving is 1/6 of one per cent of the total conversion cost, not an appreciable saving. Of the total conversion cost, about $10 is represented in labor cost. If the superior performance of direct-current driven auxiliaries results in only 1 per cent higher production, with the same labor, this saving is 10 cents per ton of ingots or 2½ times the assumed power saving.

The investment in a steel works is of the magnitude of $90, per ton of ingots. If we amortize this at 13 per cent, the fixed charges amount to about $12 per ton of ingots. If a plant equipped with direct-current auxiliary drives produces 1 per cent more output than one equipped with alternating-current auxiliaries, the reduction in fixed charges, per annual ton of output is about 12 cents per ton. This is three times the assumed power saving.

The above figures are presented to show the relative importance of performance and productivity. They indicate that, even if alternating-current auxiliaries required no power at all, the direct-current auxiliary drive might still be the preferable selection. It should be evident that the savings which may be made through the use of alternating-current auxiliaries are questionable as to their realization; but, even if realized, their possible magnitude and importance is very small. On the other hand, the possibilities for real economies to be accomplished with direct-current auxiliaries, are of an appreciable and important magnitude.

It is significant that, in considering alternating current auxiliary drives, the measure of merit is the nearness of approach to direct-current drive performance. The direct-current drive is the standard of perfection toward which the alternating-current drive would aim.

The new machinery being introduced into the steel industry is ever more exacting in its demand for good motor performance and accurate control. New developments in control such as the automatic screwdown are dependent upon the accurate performance of the direct-current drive. Today the direct-current auxiliary drive is far superior to the alternating-current drive. As the steel industry reaches greater refinement, the greater flexibility and better performance of the direct-current drive will further emphasize its superiority.

We should therefore seriously question the wisdom of a commitment to the adoption of a system of auxiliary drives and control which has greatly circumscribed possibilities and which does not offer full scope for future development.

# Association of Iron and Steel Electrical Engineers

# Inspection Trip

# A. M. BYERS COMPANY PLANT

## AMBRIDGE, PENNSYLVANIA

## THURSDAY, OCTOBER 23, 1930

### SCHEDULE AND ROUTE OF A. I. & S. E. E. INSPECTION TRIP

9:00 A. M.—Leave Pittsburgh—Pennsylvania Union R. R. Station.

9:30 A. M.—Arrive Ambridge.

10:45 A. M.—Start of Inspection Trip from Main Office of Plant.

*Departments to Be Visited*

Cupola Melting Department
Converting Department
Processing Department
Slag Melting Department
900 Ton Ingot Press
Re-heating Furnaces
Gas Producers
Boiler House
Research Laboratory
River Pump House
Machine Shop
Blooming Mill
Plate Mill
20″—18″—16″—14″—9″ Mills
Power Houses

1:30 P. M.—Luncheon—Elks Temple, Ambridge, Pa.

2:30 P. M.—Technical Session.

Chairman, G. A. Kaufman, Elec. Engineer, Jones & Laughlin Steel Corp., Pittsburgh, Pa.
Secretary, R. F. Sanner, Assistant Elec. Engineer, Carnegie Steel Co., Duquesne, Pa.

SUBJECT—DRIVES FOR ROLL TABLES

Symposium By
Engineers in Iron and Steel Industry
Electrical Engineers
Mill Builders

The A. M. Byers Company has developed a process for wrought iron manufacture which is of interest to all executives of the Iron and Steel Industry. The Ambridge Plant is modern in every respect and represents the combined talent of steel mill engineering in the United States. RESERVATIONS MUST BE MADE FOR THIS TRIP.

## A. I. & S. E. E., INSPECTION TRIP

### Notes on A. M. Byers Company Plant

Seldom is any radical innovation made in our metal manufacturing processes. Time and economic necessity have reduced our methods of manufacture to a rather well defined procedure so that changes in practice have been few. For sixty years steel has been made principally in the Bessemer converter and the open hearth furnace; and, for approximately a century and a half, wrought iron has been manufactured almost exclusively in the puddle furnace. During these years some changes have been made in the manufacture of both iron and steel, but it was not until 1926 that there was devised a process which in operation, but not in principle. was a decided departure from customary practice. By this process, designated as the "Byers Process," wrought iron of exceptionally high quality can be produced in units comparable in weight to those from an open hearth furnace.

### Puddling Process

As is well known the puddling process is carried out in a furnace in which pig iron is converted into practically pure iron by the elimination of almost all of the elements, other than iron itself. This pure iron is at one stage granular, and when in this condition the grains are covered by a bath of slag so that each grain attains a slag coating. The grains are then worked by the puddler into balls and in this form the iron is removed from the furnace. The balls are put through a squeezer and the resultant "bloom" rolled in a mill. As the metal is rolled the slag that coated the grains is elongated into thin films which become interspersed in the iron in fibrous form.

### Byers Process

In the Byers Process the procedure is analagous in principle, but the manner of achieving the same objectives is different.

Pure iron is obtained by melting pig iron in a cupola and then refining the molten metal in a Bessemer converter. This highly refined iron is carried in ladles to what is known as the "processing platform" where it is carefully poured into processing cups in which is a bath of slag. This slag, which is of an exact composition, has been prepared in an open hearth furnace and tapped into the cups. As the molten iron falls through the liquid slag it solidifies into a granular form and, as in the puddling furnace, each grain takes on a coating of slag.

A peculiar phenomenon takes place while the grains of iron are falling through the slag. As the stream of iron strikes the surface of the slag, it breaks into minute globules in the interior of which a gas instantaneously collects. While these globules are descending the gas pressure within them increases to a point where the hollow globules are completely shattered. This phenomenon, the bursting of shells of the globules, permits the particles of metal to receive a complete coating of slag; and, thus, the action which in the puddling process gives wrought iron its peculiar merit, is carried out to even a greater degree in the Byers Process.

After sufficient iron has been poured into the slag, the surplus slag is decanted and a ball similar in every respect, except weight, is found in the bottom of the cup. This ball, instead of weighing 200 pounds as in the puddle furnace, weighs from 6000 to 8000 pounds.

It is apparent that the same reactions that are basic in the puddling process are also basic in the "Byers Process," and that, therefore, the product is in every respect identical. The difference between the two processes is that in the latter the output is much greater, and for its performance there is not required the arduous and exhausting labor that is necessary for the former.

### Plant at Harmony Township, Beaver County, Pennsylvania

For years the "Byers Process" was carried on in a leased plant at Warren, Ohio. However, it became apparent that larger quarters and more adequate facilities must be provided. Accordingly on February 11th, 1929, ground was broken for the erection of a plant near Ambridge, Harmony Township, Beaver County, Pennsylvania. On October 23rd, 1930, the A. I. & S. E. E., will visit this plant.

Before the erection of the buildings at Economy, all operations had been performed on a small scale only; consequently, the equipment for the new plant had to be constructed for a much greater output than had previously been attained. With present equipment from 20,000 to 25,000 tons can be produced monthly.

The buildings in which wrought iron will now be manufactured have been erected on a tract of land of 126 acres. This tract is situated on the Ohio River 20 miles below Pittsburgh. Between the plant and the river passes the main line of the Pennsylvania Railroad.

The necessary steps in the process are as follows:

1—Obtaining a supply of pure iron.
2—Obtaining a supply of slag.
3—Processing the iron in the slag.
4—Decanting the surplus slag.
5—Pressing the ball of wrought iron into a bloom.

To carry out the first of these steps it is necessary that pig iron be melted and poured into a Bessemer converter in which the pig iron is converted into pure iron.

### Obtaining a Supply of Pure Iron

In practice this step is at present performed by melting the pig iron in three cupolas and then transferring it in a ladle car to two, ten-ton converters. It is the intention at some future time to erect a battery of coke ovens and a blast furnace so that molten iron can be carried from the furnace direct to the converters.

Into the cupolas are charged pig iron, coke and limestone. The coke supplies the heat necessary to melt the iron; the limestone provides the necessary flux to form a slag. A special treatment insures a very thorough removal of sulphur. Air to burn the coke is supplied by three blowers. When the iron is melted it is tapped from the cupola into a ladle car and in this is transferred to the converters. Every car of iron is weighed.

After the iron has been placed in the converter, it is rotated to a vertical position and a current of air at approximately twenty pounds pressure is blown through the bottom of the converter which passes up through the metal. The air oxidizes the

carbon, silicon and manganese in the pig iron and makes it practically pure iron. In about ten minutes, when this operation is finished, the converter is tilted and its contents allowed to flow into a hot metal ladle which rests on a car.

The car and ladle are then drawn by a cable to a position in front of what is known as the "processing platform." Here the ladle is lifted off the car by a crane and the metal poured into a processing ladle. This ladle sets on a specially designed car which is so constructed that it can impart to the ladle, when tilted, a forward and backward as well as a lateral motion, which insures a very even and uniform distribution of metal. Four processing ladles on cars are available on the platform.

Before the third step can be performed a bath of slag must be provided into which the iron can be "processed."

**Obtaining a Supply of Slag**

Into two tilting open hearth furnaces slag forming materials are charged in such proportions that the product will be of a definite composition. These materials are melted and, when at the desired temperatures, the liquid slag is tapped into large processing cups. Only enough slag is permitted to flow into the cups to obtain the depth of bath desired. The cups are carried on a car, several of which make up a train. Pulled by an electric engine, the train is drawn over a circular track to a point beneath the processing platform where the cup containing the slag can receive the molten purified iron.

**Processing the Iron in the Slag**

While the cup with its bath of slag stands below the processing ladle containing the pure iron, the ladle is tilted enough to allow a small stream of iron to flow into the bath. The action that ensues is termed "processing." When sufficient iron has been poured the train is moved to a position near a large press where a crane raises the cup and decants the surplus slag.

**Decanting the Surplus Slag**

As the slag flows from the cup in which processing has occurred, the ball of pure wrought iron remains at the bottom. The crane then carries the cup to a gigantic 900 ton press where the ball is made to fall onto a square platform section which forms part of the press.

**Pressing the Ball of Wrought Iron into a Bloom**

The 900 ton press in which the ball is given the form of a bloom (or ingot) has a boxlike chamber. The bottom of this chamber can be elevated to the level of the top of the sides, and it is on this square section that the ball is deposited. With the ball on it, the section lowers to its normal position and immediately the rear wall of the chamber is forced forward and the ball is squeezed so that two of its sides are flat. The mass is then turned and the same force is again applied. This pressing action is repeated until a bloom about seventeen inches by twenty-four inches is formed. The bottom section is then raised and when at its top position, a pusher shoves the bloom onto the rollers of the blooming mill approach table.

* "An unusual application of reversing mill motors is being made to operate the rams of a large ingot press which will be used to compress wrought iron sponge balls to rectangular ingot form, preparatory to rolling in a blooming mill. This installation is being made at the new plant of the A. M. Byers Company. The main ram, capable of exerting a pressure of 900 tons to form the cross-section of the ingot, will be driven by a 1200 H.P., 125 R.P.M. reversing motor, and the auxiliary 200-ton ram, which shapes the ends of the ingot, will be driven by a 325 H.P., 250 R.P.M. motor. Power is furnished by a synchronous motor generator set, consisting of a generator for each reversing motor, a 1500 H. P., 600 R.P.M., 3-phase, 60-cycle, 6600-volt, synchronous driving motor and a direct connected exciter. The generators and reversing motors are designed with special field characteristics and the control provided with automatic limit switches and speed limit governors to make the operation largely automatic and to prevent damage to the press by careless manipulation."

So far the entire process has required engineering of a pioneering nature, since there was no precedent to follow except the little engineering work done at the leased plant at Warren. The reduction of the bloom into the finished products is, however, according to practice familiar to rolling mill engineers.

**40" Blooming Mill**

This mill which is of the most modern type, is driven by a 5000 h.p. motor and will reduce the iron blooms into either slabs or billets. It is electrically controlled entirely. From the mill the slabs or billets pass to an electrically driven shear which cuts them into the lengths desired. For the storage of the slabs and billets a building 429 feet long and 100 feet wide has been built.

** "For the new plant which the A. M. Byers Company is building at Ambridge, Pa., to produce wrought iron and wrought iron pipe on a large scale, we are building several mill drives. A 40-inch reversing blooming mill will be driven by a direct-current reversing motor rated 5000 H.P., 50°, 50/130 R.P.M., 900 volts. Power for this motor will be supplied by a flywheel motor-generator set driven by an induction motor. For the 46-inch reversing universal plate mill in this same plate plant there is being built a 4000 H.P., 60/140 R.P.M., 900-volt, direct-current reversing motor which will be supplied with power by a synchronous motor driven motor-generator set without flywheels. It is believed that this is the largest reversing drive yet built which dispenses with the usual flywheels on the motor-generator set. Six direct-current motors totaling 9300 H.P. will drive two skelp mills in this same plant."

**Universal Plate Mill**

The products of this mill are plates from 12" to 84" wide, skelp for the manufacture of pipe, and forging blooms or billets.

Two furnaces are now in service for heating the blooms that are fed to the mill. These furnaces have been erected in a building 382 feet long and 100 feet wide that adjoins the building in which blooms and billets are stored as received from the blooming mill. This mill, like the blooming mill, is

*Reprinted from A. F. Kenyon's article in January, 1930, issue of Iron and Steel Engineer.

**Reprinted from J. D. Wright's article in January, 1930, issue of Iron and Steel Engineer.

operated by electrical devices of the latest and most approved type. The slabs or plates pass from the mill to a hot bed and from this to shearing tables where the sides or ends, or both, can be cut.

**20"-18"-16" Skelp Mill**

Parallel to the plate mill but in another building, a 20"-18"-16" skelp mill has been installed. In this mill will be rolled skelp for the manufacture of pipe of the smaller sizes. The mill is of the type known as continuous. Its operation is unlike that of either the blooming or universal mill in that the bloom being rolled passes from one stand of rolls to another instead of back and forth through one set of rolls. In this mill there are five stands of edging (or vertical) rolls and nine stands of horizontal rolls. The edging rolls exert a pressure against the sides of the plate and do away with the necessity of side shearing. A hot bed 160 feet long receives the skelp from the run-out table.

**9"-14" Mill**

In a building adjacent the mill just described is a mill for rolling billets into merchant mill products, viz: rounds, flats, squares and other sections. Billets to be rolled in this mill are heated in two furnaces of a design similar to those that heat slabs for the universal and skelp mill.

The billet is first passed through one stand of roughing rolls and then through five stands of finishing rolls. An 800 h.p. motor drives the roughing stand; one 800 h.p. and one 1200 h.p. motor drive the finishing stands. The product may go through a rotary flying shear to a 110 foot hot bed, or to two reels. Two roller tables carry the rods to vertical shears through which they pass to bundling tables.

All three of these mills deliver their products into a building from which they are shipped. This building is 472 feet long and has a width between crane runways of 125 feet.

# *Items of Interest*

## PERSONNEL CHANGES

W. S. Hall has been made Superintendent of Engineering and Construction of the Illinois Steel Company, South Works, South Chicago, Ill. He was formerly Assistant Chief Engineer. Mr. Hall was President of the A. I. & S. E. E. in 1922. He is extremely active in Association activities and has contributed many valuable papers and articles to the Association Proceedings. The Association membership are extending their best wishes for his success in his new position.

The Roller Smith Company of New York, N. Y., announce the appointment of J. K. Webb, as its District Sales Agent for the State of Texas. Offices are located in 601 Allen Building, Dallas, Texas.

James H. Reniers, formerly Electrical Engineer of the Pittsburgh Screw and Bolt Company of Pittsburgh, Pa., has been made Assistant General Superintendent. Mr. Reiners is an active member of the A. I. & S. E. E. and the membership are extending their congratulations.

William V. Weber has resigned his position as Chief Electrical Engineer of the American Welded Tube Company of Brilliant, O.

Ralph A. Young has been made Metallurgist of the Marion Steam Shovel Company of Marion, O. He was formerly Assistant Metallurgist. H. B. Kinnear, formerly Metallurgist of the above company has resigned.

The Boston office of the Reliance Electric and Engineering Company, manufacturers of alternating and direct current motors have moved from 80 Federal street to their new quarters at 89 Broad street. R. H. Smith will continue as District Manager of this territory.

Eric Zachau has resigned his position as Western Sales Manager of the Manning Maxwell & Moore, Inc., Shaw Crane Department. Mr. Zachau joined the Manning Maxwell & Moore Company in December, 1903, as Electrical Engineer, which position he held until August, 1915. He was then made Sales Engineer in Pittsburgh and held that position until November, 1920. He was then made Chief Engineer and in March, 1922, was made Works Manager. Mr. Zachau has been a member of the Association of Iron and Steel Electrical Engineers for the past seventeen years and has a host of friends in the Iron and Steel Industry.

L. B. Mead of Indianapolis has been made Assistant Industrial Manager of the Northwest District of the Westinghouse Company. William J. Morgan of Indianapolis becomes Indianapolis Manager for the firm.

E. S. Conrad, who has been Coast District Manager for the Square D Company for ten years, has just been appointed General Sales Manager of the Diamond Electrical Manufacturing Company. This concern is affiliated with the Square D Company.

Fred T. Whiting has been appointed Assistant Manager of the Northwestern district for Westinghouse Electric and Manufacturing Company, under N. G. Symonds, Commercial Vice President.

A. R. Smith has been appointed Executive Engineer of the turbine engineering department of the General Electric Company to succeed the late William J. Delles.

C. E. Stephens, Vice President, Westinghouse Electric and Manufacturing Company, has announced the appointment of T. R. Langan as Assistant Northeastern District Manager of the Westinghouse organization.

Effective September 15th, Mr. B. L. Donahue became manager of the Buffalo District office of Cutler-Hammer, Inc., Pioneer Manufacturers of Electric Control Apparatus—whose headquarters are at Milwaukee, Wis. Mr. Donahue succeeds Mr. B. A. Hansen who has resigned.

Mr. Donahue is widely known in the electrical field, having been connected with the Pittsburgh branch office of C-H for the past eight years.

He is a graduate of Penn State College, class of '20, and holds the degree of B. S. in Electrical Engineering. He is a member of the Association of Iron and Steel Electrical Engineers.

The Carnegie Steel Company, Pittsburgh, Pa., announces the following changes in their personnel. Mr. F. E. Kling, who was Chief Engineer at the Ohio Works at Youngstown, Ohio has been made Chief Engineer over all plants with offices at Pittsburgh. Mr. James E. Lose, who was formerly Assistant General Superintendent of the Homestead, Carrie Furnace and Howard Axle Works has been made General Superintendent of the Homestead Steel Works, Carrie Furnaces and Howard Axle Works. Mr. W. S. Unger formerly Superintendent of the Carrie Furnace Plant has been made Assistant General Superintendent of the Homestead Steel Works, Carrie Furnaces and Howard Axle Works.

Mr. E. C. Ryan who was formerly District Manager of the Chicago District of the Electric Controller & Manufacturing Company has been made District Manager of the Buffalo Offices of this same company. Mr. A. A. Piper, located at Cincinnati has been made District Manager of the Chicago Office. Mr. W. C. Jackson, who was located at Buffalo has been transferred to Cincinnati.

R. J. Wysor, Vice President in charge of operations of the Republic Steel Corporation, has announced the appointment of C. A. Thayer as Chief Engineer for the corporation, with headquarters at Youngstown. Mr. Thayer has had long experience with large steel and engineering companies. His most recent connection was with Arthur G. McKee & Co. as Chief Engineer for that company's project for building a huge steel works in Russia. From 1920 until early in the present year Mr. Thayer was Chief Engineer at the Gary Works of the Illinois Steel Company.

E. O. Burgham has been made Manager of the Tin Plate Department, Weirton Steel Company. His former position was Assistant Manager.

At a meeting of the Executive Committee of Manning, Maxwell & Moore, Inc., held September 23, 1930, Frederick M. Kreiner was elected a Vice President of the company. Mr. Kreiner will continue his duties as Treasurer of the company which position he has held since 1920.

Mr. Kreiner has been connected with Manning, Maxwell & Moore, Inc., since 1903.

## WITH THE MANUFACTURERS

The Clark Controller Company, of Cleveland, O., has acquired control of the Sundh Electric Company, of Newark, N. J., through purchase of common stock. The operation will be continued under the name of Sundh Electric Company.

A new catalog featuring Brown Indicating, Recording and Automatic Control Pyrometers has just been issued by The Brown Instrument Company, Philadelphia, Pa. This catalog contains 104 pages with 141 illustrations, many of which are in two or more colors. A comprehensive resume of the theory and practice of applied pyrometry is presented, together with descriptions and illustrations of all instruments, thermocouples, protecting tubes and other required equipment.

Cutler-Hammer, Inc., 157 Twelfth street, Milwaukee, Wis., have redesigned their entire line of type AAA automatic starters for small A.C. motors, to incorporate a newly developed "Twin Break" magnetic contactor. This new contactor provides many features which are of interest. The contacts are of heavy coin-silver which retains its current carrying capacity even if oxidized and always makes a good contact with little temperature rise. The "Twin Break" principle reduces the arc voltage by half, and Thermoplax arc pockets, by reducing the air content around the contacts, actually prevents the formation of a destructive arc. These arc pockets also act as a shield so that wires which are run along the side of the contactor cannot interfere with its operation.

A magnetic latch has been added to prevent accidental closure of the contacts if the starter is accidentally bumped or tilted—the latch must be drawn aside by the operating magnet before the contacts can close. This is an important feature, especially if the starter is mounted on moving machinery. A new hinge structure facilitates removing and replacing the contact board and insures correct replacing of the board before the starter can operate.

These new contactors are made in three and four pole types. The maximum rating for two or three phase are: 3 H.P., 110 volts; 5 H.P., 220 volts, and 7½ H.P., 440 or 550 volts.

Fractional size electric motors both A.C. and D.C. up to 1 H.P. can be supplied by The Ohio Electric Manufacturing Company, of Cleveland, O.

The Allis-Chalmers Manufacturing Company, of Milwaukee, Wis., are distributing a new leaflet 2124 on their Type "ARZ" Totally Enclosed Fan-Cooled Motor. Copy of this leaflet will be mailed to interested parties, upon request.

The Carnegie Steel Company has ordered from the Westinghouse Electric and Manufacturing Company, for installation in the McDonald, O., mill, ten motors, including one 250 H.P., two 600 H.P., four 800 H.P., and three 900 H.P.; two 2,000 Kw. motor-generator sets, and the control and speed matching equipment, all of which are for the operation of a new 10" bar, 12-stand mill, making both round and square bars from ⅜" to 1¼" thick.

Two of the 800 H.P. motors are vertical and are to be mounted above the mill itself. This new mill is especially interesting because it is the first to use vertical main rolls and main roll motors, the purpose of this arrangement being the elimination of the necessity of twisting the hot steel in the rolls.

A new ball bearing data book has been just brought out by the New Departure Manufacturing Company. The designer may determine, from the information given, exactly the type of bearing his job requires. Instant reference to that type gives him a list of all sizes available as well as their dimensions and capacities at various speeds. The section devoted to determination of bearing sizes is particularly clear and well arranged. From the formulae given, any designer or draftsman can select his bearings according to the length of service required in his machine.

Every designer should have a copy and may obtain one by addressing The New Departure Manufacturing Company, Bristol, Connecticut.

The subject of the installation of better lighting systems in industrial plants is covered in a very clear and concise manner. Beginning with the planning of the system from the standpoint of the light-

ing engineer, the book goes on to tell of the benefits to be derived through the cutting down of errors and spoilage; lessening of accidents; improved morale; greater amount of work turned out; putting to profitable use dead floor space, and many other advantages of better lighting.

There are floor plans with typical installations showing the proper mounting heights and spacing of light units. Also information on the use of the foot-candle meter, wiring data, illumination calculation tables, etc.

The Benjamin Electric Manufacturing Company, Des Plaines, Ill., has published a revised and enlarged edition of the hand-book, "A Guide to Productive Lighting for Industry."

A number of typical illustrations showing before and after pictures where installations have been made with Benjamin lighting equipment, and the complete line of Benjamin reflectors and other lighting fixtures are described. It is a most complete summing up of the advantages of better lighting and the way to get it.

## WESTINGHOUSE MEMORIAL DEDICATED

### Leaders in Science and Industry Present as Monument to Great Industrial Leader is Unveiled

The nation's leaders of industry, business, and scientific research paid homage to the late George Westinghouse, founder of the many Westinghouse industries, in the dedication of a memorial to the industrial leader in Schenley Park, Pittsburgh, on Monday afternoon, October 6.

Assembled in a setting of unusual natural beauty, they observed the unveiling of the monument erected by the Westinghouse Memorial Association, composed of 54,251 members, mostly Westinghouse employees, who, with the assistance of appropriations made by the Westinghouse Electric and Manufacturing Company and the Westinghouse Air Brake Company, financed the undertakings.

The dedicatory ceremony, which began at 2 o'clock, was presided over by E. M. Herr, Vice Chairman of the Board of Directors of the Westinghouse Electric and Manufacturing Company. The program included addresses by A. L. Humphrey, President of the Westinghouse Air Brake Company and one of the leaders in the movement for providing the memorial; James Francis Burke, former congressman and now general counsel of the Republican National Committee, and Bishop Alexander Mann of the Pittsburgh Episcopal Diocese.

## ASSOCIATION NOTES

Plans are now being made for an Inspection Trip by the A. I. & S. E. E. to the Steubenville Plant of the Wheeling Steel Corporation. The date of the trip will be early in December. The Steubenville Plant of the Wheeling Steel Corporation is one of the most modern in the United States and the Inspection Trip will be of exceptional interest to every steel mill engineer in the industry.

The Chicago District Section held their Annual Golf Tournament September 16, 1930, at the Oak Hills Golf Club. About 100 members and guests enjoyed this outing. Dinner was served at 8 o'clock. The following firms contributed prizes:

Alliance Machine Company, Allis-Chalmers Manufacturing Company, Benjamin Electric Manufacturing Company, Clark Controller Company, Central States General Electric Company, Cleveland Crane and Engineering Company, Crocker-Wheeler Company, Crouse-Hinds Company, Inc., Cutler-Hammer, Inc., Delta Star Electric Company, Electric Controller and Manufacturing Company, Esterline Angus Company, V. V. Fittings Company, Freyn Engineering Company, Graybar Electric Company, General Electric Company, Harnischfeger Corporation, C. H. Hollup Company, I.T.E. Circuit Breaker Company, Paul W. Koch, Company, LeCarbone Brush Company, Morganite Brush Company, Inc., J. W. Murphy Co., National Carbon Company, R. D. Nuttall Company, Okonite Company, Ohio Electric Manufacturing Company, Pyle National Company, Reliance Electric and Engineering Company, Rowan Controller Company, Shaw Crane Works, Tool Steel Gear and Pinion Company, and Westinghouse Electric and Manufacturing Company.

## OBITUARIES

H. A. Lewis, Electrical Superintendent with the Alan Wood Steel Corporation, died Friday morning, October 3, at his home in Norristown, Pa.

Mr. Lewis was an active member of the Association of Iron and Steel Electrical Engineers and enjoyed a national reputation as an inventor and designer of steel mill equipment. The membership of the A. I. & S. E. E. offers its sympathies and condolences to the relatives.

Victor Carples, a prominent member of the A. I. & S. E. E., died suddenly September 3, 1930. Mr. Carples was associated with L. J. Wing Company of New York.

It is with the deepest regret that we advise of the death, on Thursday, September 18, of Charles Curtiss Coventry, President and Treasurer of The Cleveland Tool and Supply Company, of Cleveland, O. He passed away at his home in Cleveland, after a very brief illness from pneumonia, and had been active at his office until a few days before his death.

**STATEMENT OF OWNERSHIP, MANAGEMENT, ETC., OF**

**IRON AND STEEL ENGINEER**

(Required by Act of Congress of August 24, 1912)

Name of Publication: Iron and Steel Engineer, published monthly at Pittsburgh, Pa. (Report of October 1, 1930.)
Editor—John F. Kelly, Empire Bldg., Pittsburgh, Pa.
Business Manager—John F. Kelly, Empire Bldg., Pittsburgh, Pa.
Names and addresses of stockholders holding 1 per cent or more of total amount of stock: None.

**Board of Directors**

President, F. O. Schnure, Bethlehem Steel Co., Sparrows Point, Md.
First Vice President, J. J. Booth, National Tube Co., Gary, Ind.
Second Vice President, J. D. Donovan, Republic Steel Corp., Massillon, O.
Treasurer, W. E. Miller, Bethlehem Steel Co., Johnstown, Pa.
Secretary, W. H. Burr, Lukens Steel Co., Coatesville, Pa.
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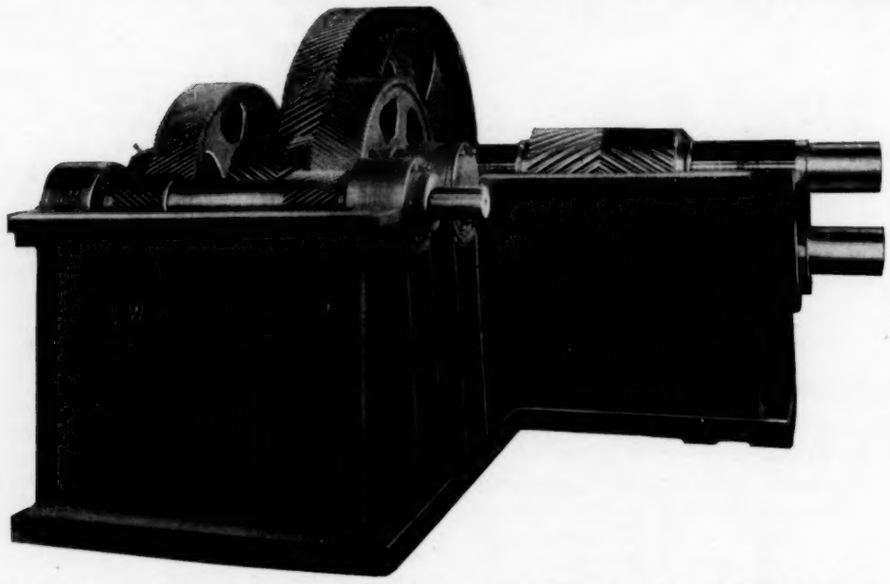
Honorary Director, J. A. Farrington, Wheeling Steel Corp., Steubenville, O.
Honorary Director, E. Friedlaender, Pittsburgh, Pa.
Known bondholders, mortgagees and other security holders owning or holding 1 per cent or more of total amount of bonds, mortgages or other securities: None.

JOHN F. KELLY, Editor.

Sworn to and subscribed before me this 1st day of October, 1930.
ETHEL M. RITTINGER, Notary Public.
(My commission expires January 21st, 1933.)

# Smooth Finish Strip Free From Chatter Marks With FARREL-SYKES GEARS



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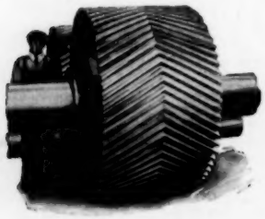
The combination of the continuous herringbone tooth and the 30° helical angle with the accuracy in tooth division and contour results in gears which transmit the power with almost perfect smoothness and quietness, with the result that the surface of the rolls has uniform angular velocity. Under these conditions the finished stock will pass the most rigid inspection.



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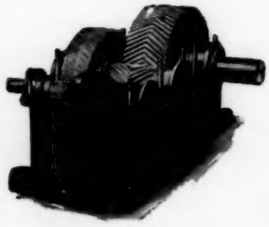

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